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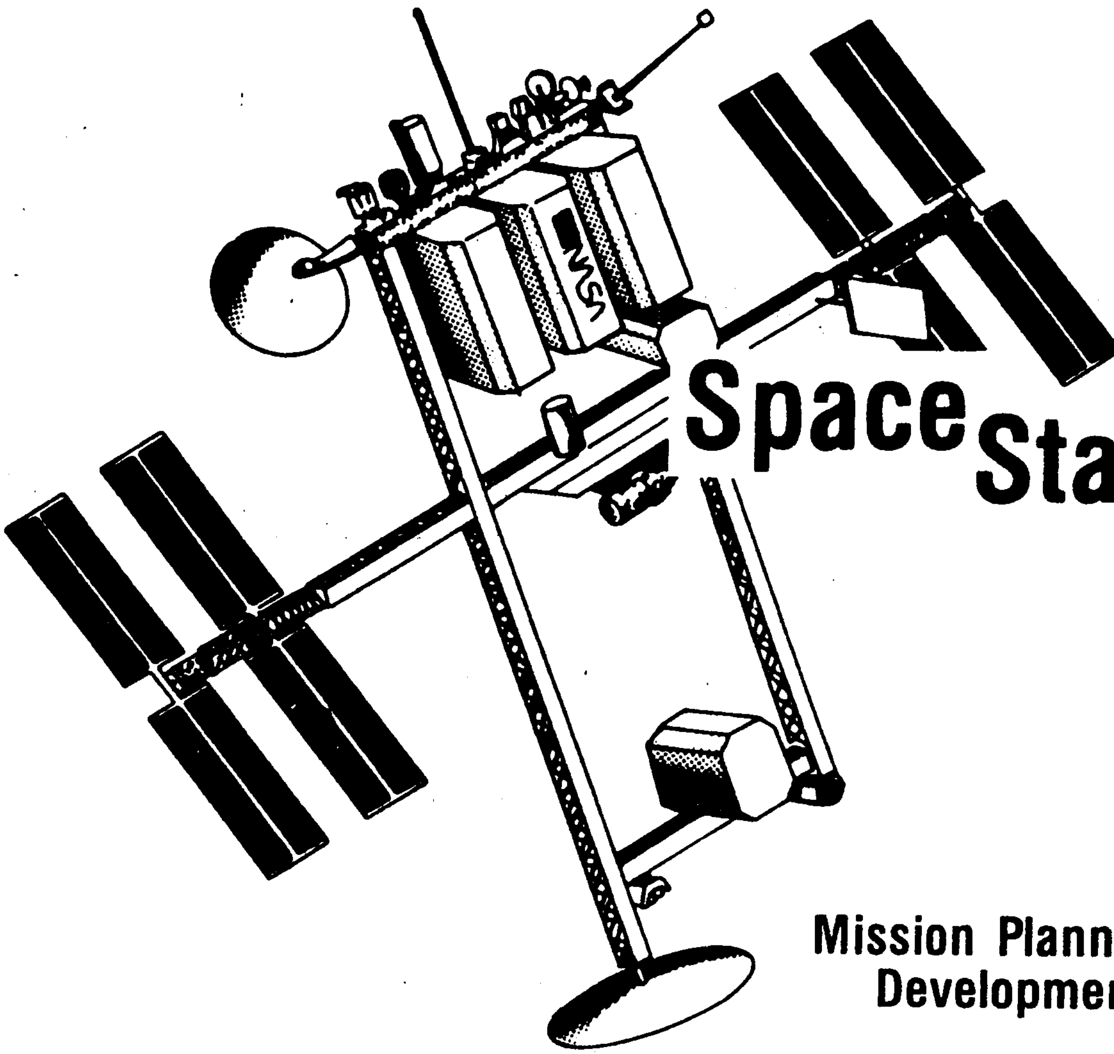

Space Station

Mission Planning System Development Study

Final Report
Volume I - Executive Summary

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY
HUNTSVILLE DIVISION

MCDONNELL DOUGLAS CORPORATION

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Space Station

Mission Planning System (MPS) Development Study

Final Report
Volume I - Executive Summary

PREPARED BY: W. J. Klus
Project Manager

APPROVED BY: E. M. Chewning
Manager, Space Station Projects

PREPARED FOR THE NATIONAL AERONAUTICS AND SPACE ADMINISTRATION. GEORGE C. MARSHALL SPACE FLIGHT CENTER. UNDER CONTRACT NO. NAS8-37275. EFFECTIVE DATE: 23 MAY 1986

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY
HUNTSVILLE DIVISION
P.O. BOX 1181
HUNTSVILLE. AL 35807

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FIGURES

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Section 1

INTRODUCTION

1.1 PURPOSE AND SCOPE

This volume presents an executive summary of the final report of the Space Station (SS) Mission Planning System (MPS) Development Study, NASA Contract NAS8-37275.

Sections 2 through 5 contain summaries of the activities, methodologies, achievements, and results of the major study tasks. The final section provides a summary of major conclusions and recommendations.

1.2 STUDY OBJECTIVES

The basic objective of the SS MPS Development Study was to define a baseline Space Station mission planning concept and the associated hardware and software requirements for the system. Specific objectives in support of the basic objective were the following:

a. Develop a mission planning concept which is consistent with the overall Space Station operations philosophy.

b. Define and assess the capability of the Spacelab mission planning system for use in Space Station mission planning consistent with the concept developed under objective a.

c. Determine and recommend where Artificial Intelligence (AI) concepts and techniques can be effectively utilized for Space Station mission planning. AI areas to be investigated for application to the specific requirements of mission planning include natural language interfaces, expert systems, and automatic programming.

d. Construct a software development plan for a phased development of a Space Station mission planning system. The plan shall consider the modifications identified in objective b, and the implementation of any AI concepts recommended in objective c. The plan shall include a schedule and a manpower estimate.

1.3 TECHNICAL APPROACH

The SS MPS Development Study included the following tasks to accomplish the study objectives:

Task 1	-	Orientation
Task 2	-	Review Spacelab Mission Planning Process and Software
Task 3	-	Space Station Mission Planning Software Requirements
Task 4	-	Investigate Artificial Intelligence Applications to Mission Planning
Task 5	-	Mission Planning Software Development Plan

The flow of these tasks is reflected in Figure 1.3-1.

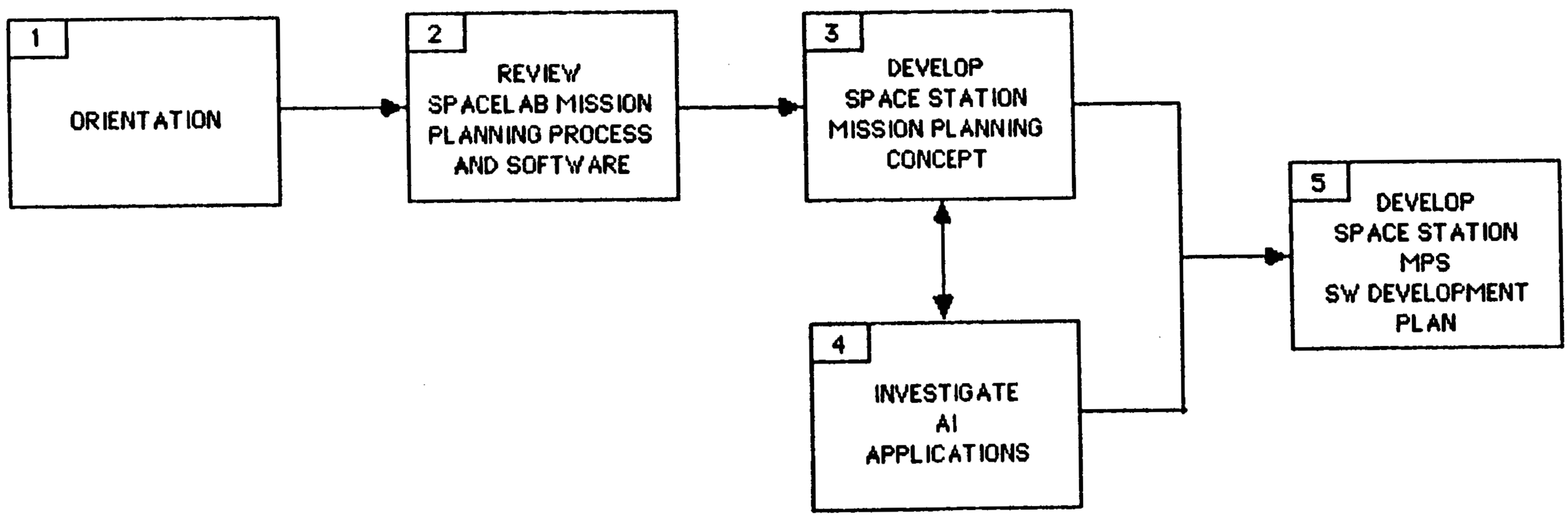


FIGURE 1.3-1 SS MPS DEVELOPMENT STUDY TASK FLOW

Task 1 allowed the study team to obtain an initial familiarization with the process and existing software used for Spacelab payload mission planning at MSFC and to travel to other NASA centers to obtain a general familiarization with the processes and software in use for mission planning at those centers.

The objective of Task 2 was to establish a complete baseline definition of the Spacelab payload mission planning process, along with a definition of existing software capabilities for potential extrapolation to the Space Station era. Areas which were included were orbital mechanics analysis and planning, mission timeline generation, data flow analysis and planning, onboard computer timelines generation and implementation, experiments command planning and implementation, and planning for Payload Operations Control Center (POCC) support. Preflight planning and real-time planning and replanning activities were also defined. The process definition was defined using detailed functional flow diagrams, and individual software module functions.

Task 3 used the information developed in Task 2 for the Spacelab payload mission planning process and software as the basis for defining requirements to support Space Station mission planning. The system was designed to permit the mission planning function to be centralized or distributed, and to be performed by non-expert mission planners as well as experts. The role of mission planning onboard the Space Station and the interfaces with the ground were assessed. Initially, five Space Station mission planning concepts were identified for assessment; these ranged from all mission planning done on the ground to all mission planning done on-board the Space Station. Subsequent MSFC guidance narrowed the possible concepts to one in which mission planning was to be done on the ground with minor real-time replanning capability to be provided on-board. Comparable to the Spacelab process, detailed flow diagrams of the Space Station mission planning concept were developed, including the flow of planning data. Also, software functions were identified, and modifications/additions to the Spacelab payload mission planning system software to support the Space Station mission planning concept were defined.

In Task 4, the Space Station mission planning concept (developed in Task 3) was reviewed for the purpose of identifying areas where Artificial Intelligence (AI) concepts might offer substantially improved capability. Three specific AI concepts were investigated for applicability: natural language interfaces, expert systems, and automatic programming. The advantages and disadvantages of interfacing an AI language with existing FORTRAN programs or of converting totally to a new programming language were identified.

Task 5 integrated the outputs of Task 3 and 4 to produce the primary product of the Study, a Space Station Mission Planning System Software Development Plan. The plan includes:

o A detailed description of modifications and additions to the Spacelab mission planning system which are required in order to make this system suitable for use in Space Station mission planning.

o Recommendations on the use of AI as means of improving the overall mission planning process, including identification of specific areas where AI may be beneficial.

o A development schedule compatible with the overall Space Station schedules, and the manpower required.

The development plan includes a description of the Space Station mission planning concept, a review of the functions to be performed, and a description of the modules required for each function. Module development standards, such as language used for coding, are also defined.

Section 2

SPACELAB MISSION PLANNING PROCESS AND SOFTWARE

2.1 ACTIVITIES AND ACCOMPLISHMENTS

The purpose of Task 2 was to review the current Spacelab (SL) payload mission planning process and software and to develop a complete definition and understanding of the process and Mission Integration Planning System (MIPS). The approach taken for this task was first to develop an upper level Spacelab functional flow diagram, then to group the major activities from the overall diagram into major functional areas of activity (which tended to correspond to MSFC mission planning organizational elements), and finally, for each functional area, to develop detailed flows to a level sufficient to acquire a thorough understanding of the mission planning activities and to be able to correlate the capability of a SL MIPS software module to the objective of a specific activity. Based on knowledge gained, a computerized data base of mission planning activities, activity descriptions, and resource data was also developed.

The major inputs to the task were MSFC briefings, demonstrations and handout materials, Spacelab mission planning process and software documentation, and personal interviews with Spacelab mission planning personnel. By far the most valuable of these inputs were the interviews/working sessions with mission planning personnel for development of the functional flows. Mission planning personnel also made certain inputs to the data base which could only be provided by people who were experienced in the SL mission planning process. The support of these NASA personnel was essential in accomplishing this task.

The major products of this task were the Spacelab mission planning process functional flow diagrams and Spacelab MIPS data base. These products, and the knowledge gained from their development served as a significant input to Task 3 because they identified not only the SL Payload MIPS software modules of potential applicability to Space Station, but also a detailed understanding of the scope, nature, and sequence of activities and inputs/outputs that are required for the planning of payload on-orbit operations in general.

This task revealed certain characteristics and lessons learned from the Spacelab payload mission planning that served as important considerations in the establishment of the fundamental objectives and approach toward Space Station mission planning in Task 3. These characteristics and lessons learned are presented below:

- Spacelab mission planning activities are centralized.
- Payload activities are scheduled down to the minute to make maximum utilization of resources during a short-duration mission.
- The collection of principal investigator experiment operations requirements is a very sizable manual effort which continues through all planning cycles.

- Spacelab mission planning employs a system of 58 actively used computer programs which have evolved over a ten-year period without the benefit of a rigidly controlled, structured process of development (Upgrading of capabilities is still underway).

- Though employing computer software, the Spacelab mission planning process involves considerable manual effort of highly skilled personnel.

- User-friendly interactive and automated software is considered of key importance to reducing mission planning manpower requirements.

2.2 FUNCTIONAL FLOW DIAGRAMS

2.2.1 Spacelab Functional Flow Diagram

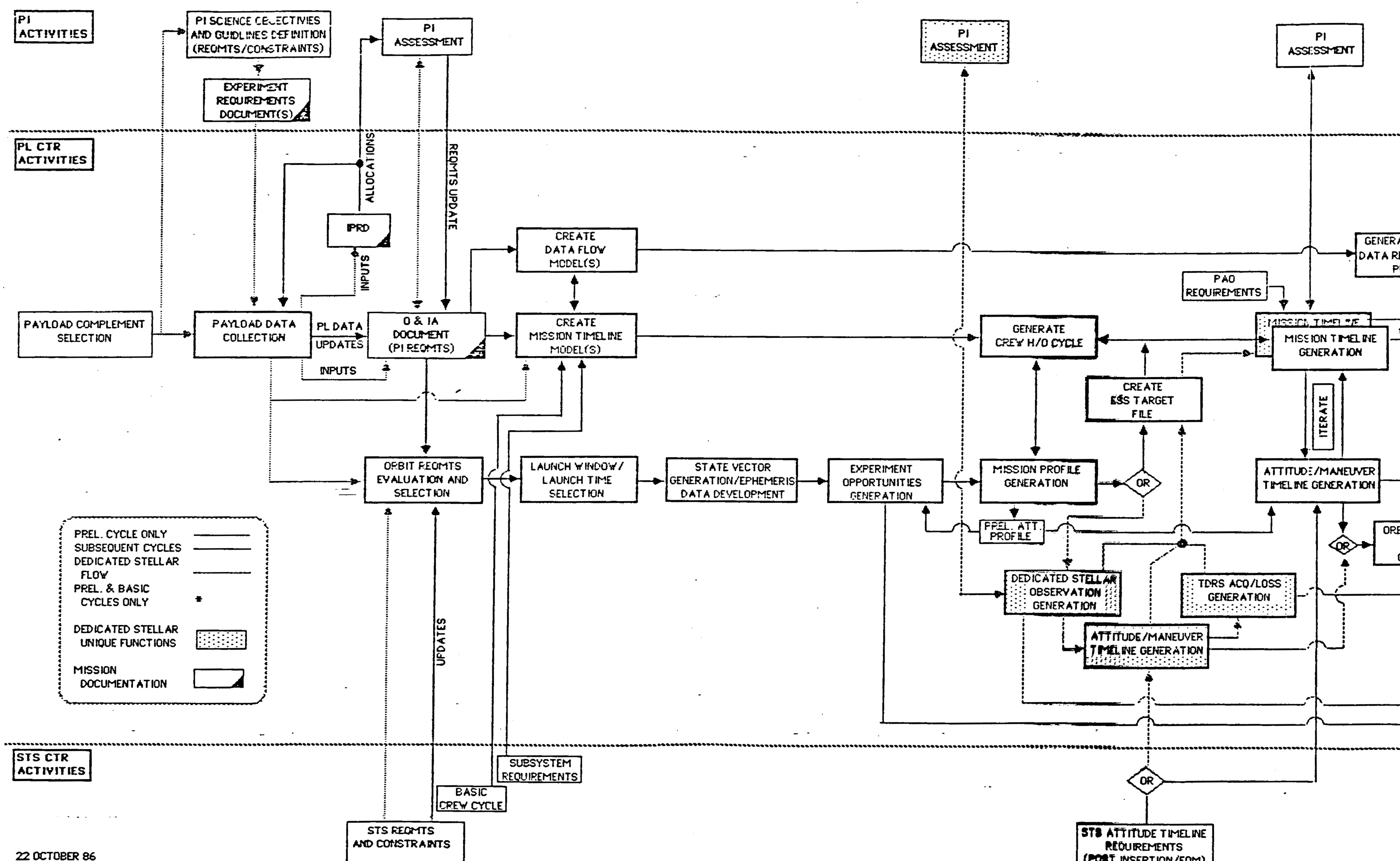
An upper level Spacelab Functional Flow Diagram (Figure 2.2.1-1) was developed in order to identify all major activities of the Spacelab payload mission planning process. The diagram shows interfaces required by the planning center (MSFC) with the Principal Investigators (PI's) and with the STS center (JSC). The diagram includes activities ranging from payload data collection, through the required analyses, to preparation of payload mission execution documentation. The activities for three (3) planning cycles (preliminary, basic, update) are encompassed by the flow except where noted by the diagram legend. Real-time replanning activities are also encompassed by the flow. The flow accommodates a multidiscipline payload complement but includes a unique path for a payload complement of co-aligned IPS-mounted stellar observation experiments.

The SL mission planning process activities depicted in the Spacelab Functional Flow diagram are grouped into nine (9) major functions. These functions are:

- Payload Data Collection
- Orbit Analysis
- Mission Timeline Analysis
- Flight Definition Document Development
- Flight Planning Annex Input Development
- Crew Procedures Development
- Data Flow Analysis
- MMU Load Input Development
- Experiment Command Planning Development

2.2.2 Spacelab Detailed Flow Diagrams

The SL mission planning process detailed flows break down the functions to a subfunction/task/subtask level necessary to understand the mission planning activities, or to a level necessary to correlate a particular software module to an activity.



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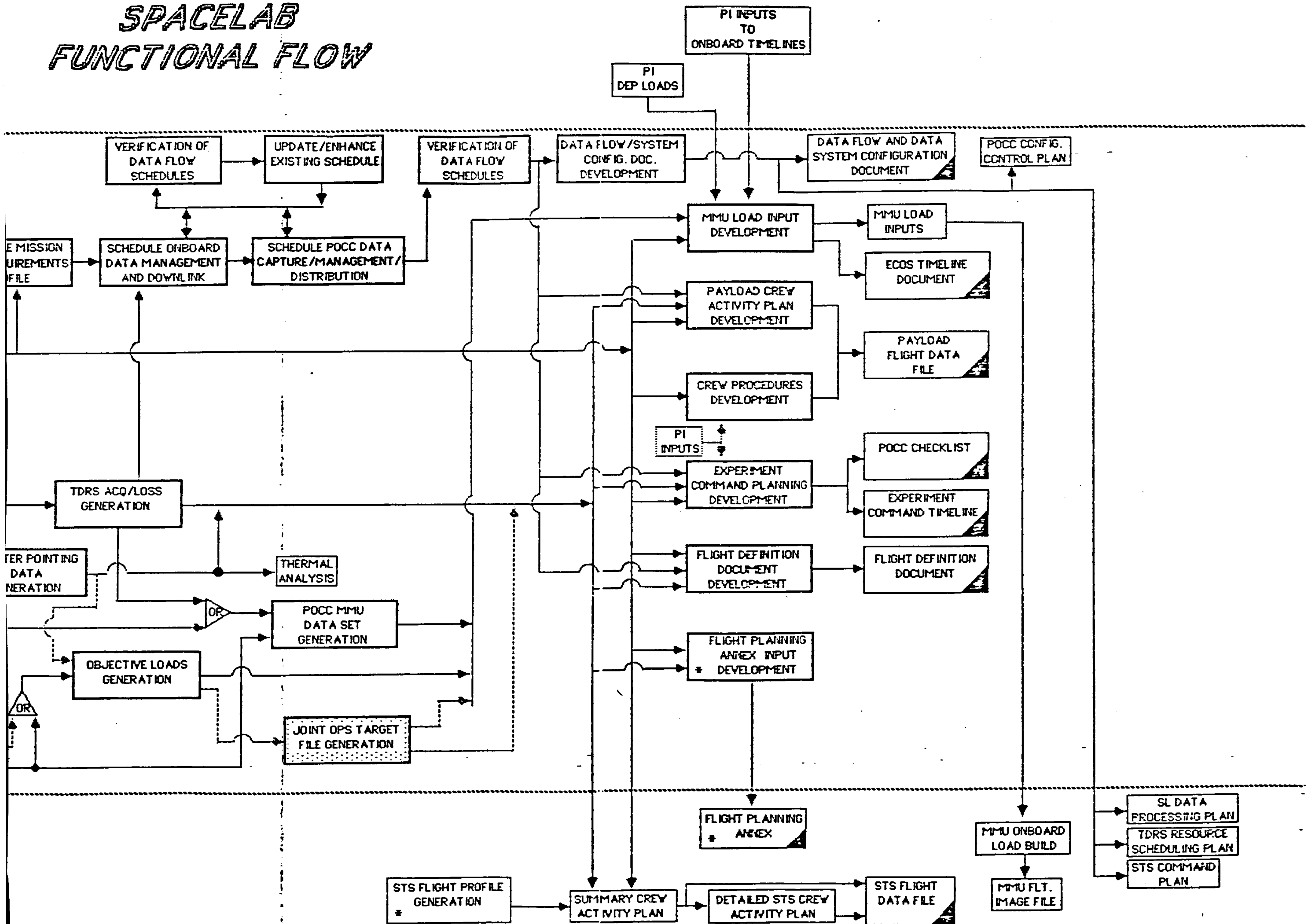
FOLDOUT FRAME

2 FOLDOUT FRAME

FIGURE 2.2.1-1.

SPACELAB FUNCTIONAL FLOW



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Activities may be manual, automated, or a combination of manual and automated. Manual activities normally include the collection of information (verbal inputs, informal or formal documentation), the evaluation and assessment of this information, and the publication of the results (informal or formal documentation). However, some manual activities produce a computerized input for a subsequent activity - e.g., use of the VAX editor to create a computerized file for use by a software module in a subsequent automated activity.

Automated activities include a software module, based on some fixed algorithm, which reads a computerized input file(s) (fixed format), performs specific operations on the input data, and then outputs the results as either a computerized output file(s) or as a printout. Some automated activities require, or permit, manual inputs to the software module via a keyboard.

Figures 2.2.2-1 and 2.2.2-2 are representative examples of the detailed flow diagrams developed to fully define the Spacelab payload mission planning process. Figure 2.2.2-1 provides a more detailed definition of (i.e., identifies the flow of tasks which comprise) the orbital analysis subfunction "Experiment Opportunities Generation" from the top-level Spacelab Functional Flow Diagram (Figure 2.2.1-1). In turn, Figure 2.2.2-2 identifies the flow of subtasks which comprise the task "Generate Plasma Physics Targets" from Figure 2.2.2-1. Shown in these figures are manual/automated activities and associated manual/automated inputs/outputs. For each automated subtask in Figure 2.2.2-2, the name of the SL MIPS software module used to accomplish the subtask is indicated in the lower right-hand corner of the subtask block.

2.3 SPACELAB MIPS DATA BASE

The SL MIPS data base was developed in order to provide activity summary data, software description and requirements data, and activity time and skill requirements data. The level of detail of the data base is consistent with the level of detail in the Spacelab mission planning process detailed flow diagrams; that is, entries exist in the data base corresponding to each lowest-level activity block identified in the flow diagrams. In conjunction with the detailed flows, the data base provides a comprehensive definition of the Spacelab payload mission planning process.

The data base consists of eight (8) interrelated tables of data:

- Activity Summary Data
- Activity Time and Skill Requirements
- Software Used by Activity
- Software Description
- Software Peripherals Required
- Activity Input/Outputs
- Computer Input/Output Summary
- Manual Input/output Summary

Figures 2.3-1 through 2.3-8 provide representative examples of the data in these tables. The outlined entries correspond to the subtask "Develop/Apply Constraints to BORB Parameters".

FUNCTION: ORBITAL ANALYSIS
SUBFUNCTION: EXPERIMENT OPPORTUNITIES GENERATION

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OF POOR QUALITY

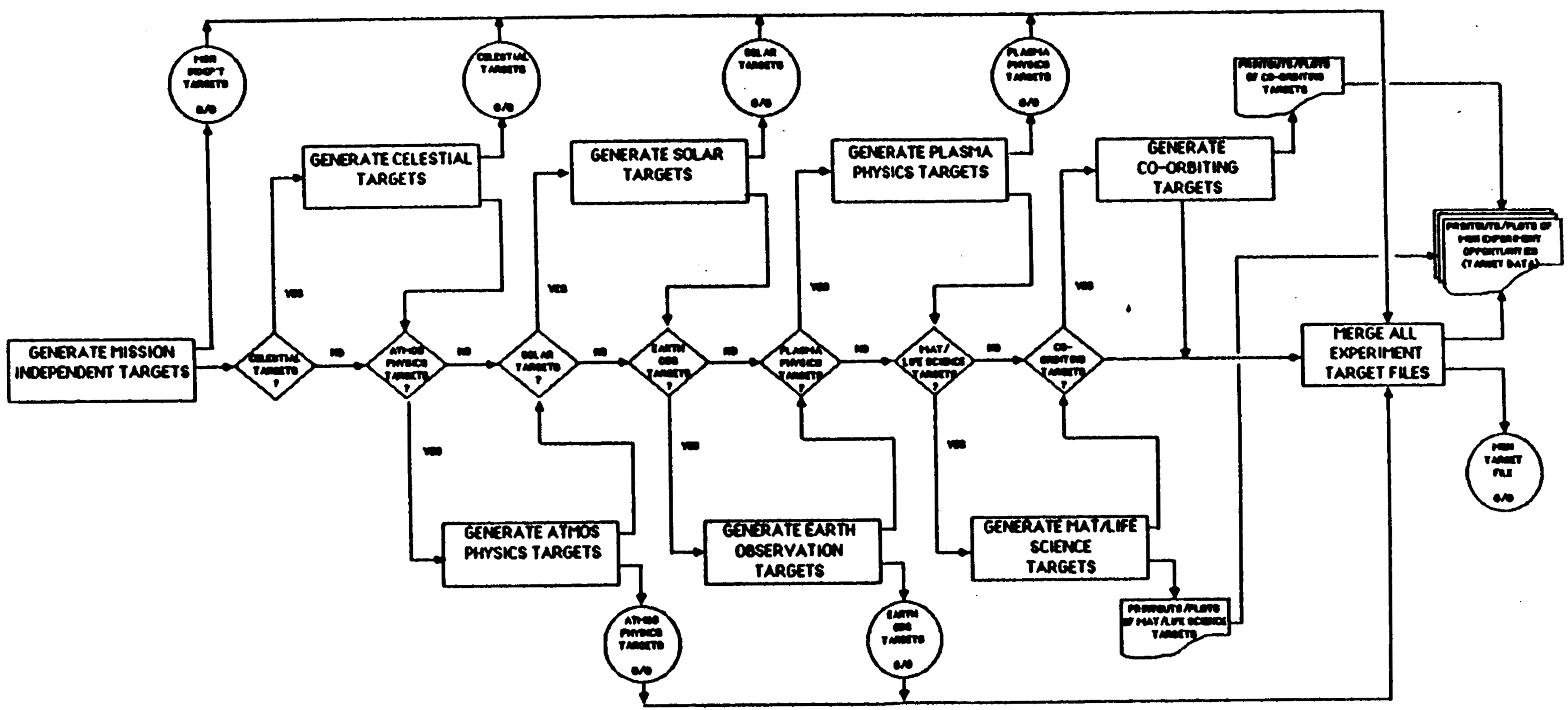

FIGURE 2.2.2-1. EXPERIMENT OPPORTUNITIES GENERATION

FUNCTION: ORBITAL ANALYSIS
SUBFUNCTION: EXPERIMENT OPPORTUNITIES GENERATION
TASK: GENERATE PLASMA PHYSICS TARGETS

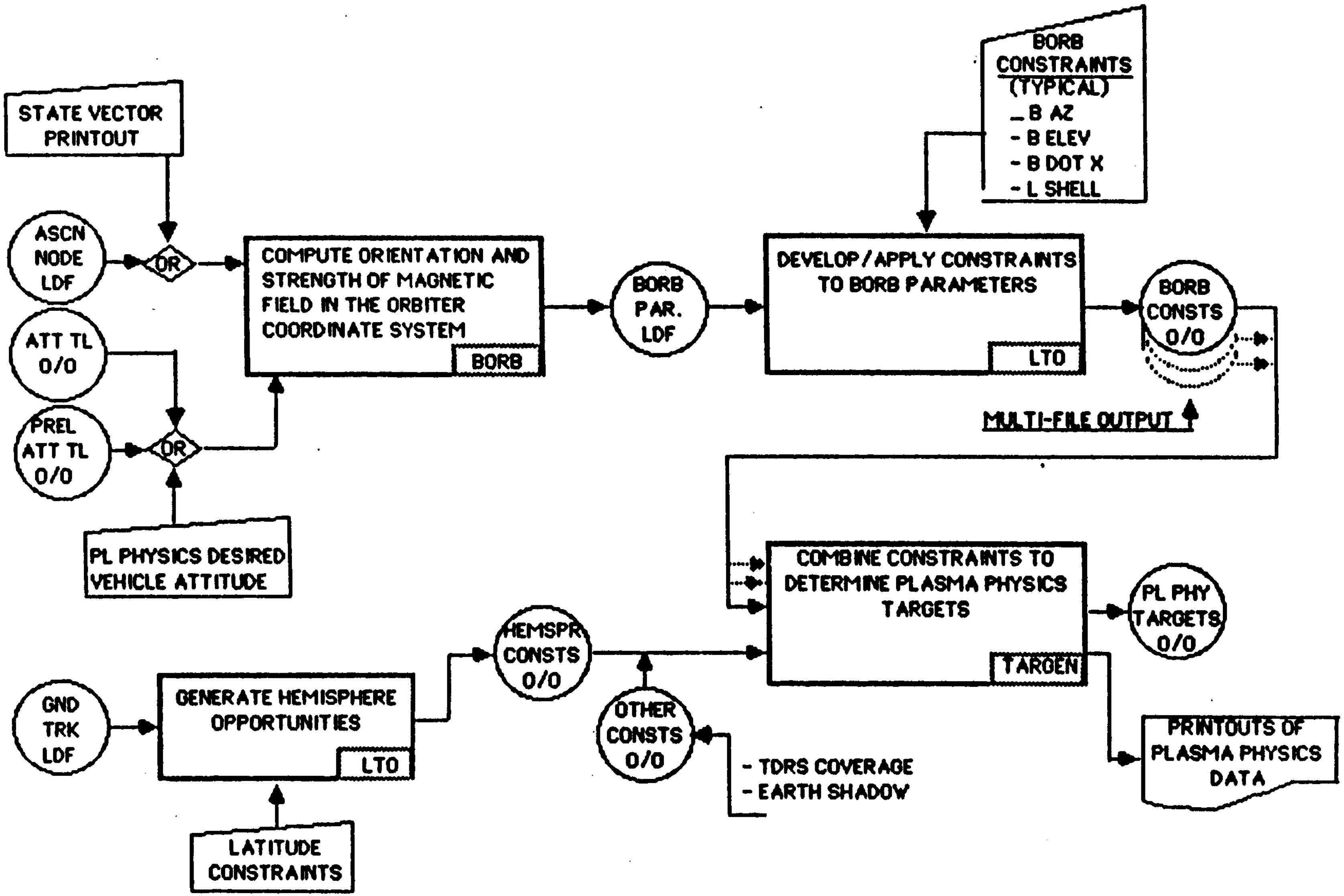

FIGURE 2.2.2-2. GENERATE PLASMA PHYSICS TARGETS

ACTIVITY SUMMARY DATA

DATE 03/19/87

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FUNCTION	SUBFUNCTION	TASK	SUBTASK	ACTIVITY OBJECTIVE	METHOD	NEED
ORBITAL ANALYSIS	EXPERIMENT OPPORTUNITIES GENERATION	GENERATE EARTH OBSERVATION TARGETS	GENERATE ACQ/LOSS OF GROUND SITE TARGET AREAS	GENERATE ACQUISITION AND LOSS TIMES OF THE DEFINED EARTH TARGET AREAS.	AUTOMATIC	ROUTINE
ORBITAL ANALYSIS	EXPERIMENT OPPORTUNITIES GENERATION	GENERATE EARTH OBSERVATION TARGETS	DEVELOP/APPLY CONSTRAINTS TO EARTH OBSERVATION TARGETS	DEVELOP EARTH OBSERVATION PERIODS WITHIN ACCEPTABLE CONDITIONS.	AUTOMATIC	ROUTINE
ORBITAL ANALYSIS	EXPERIMENT OPPORTUNITIES GENERATION	GENERATE EARTH OBSERVATION TARGETS	COMBINE CONSTRAINTS TO DETERMINE EARTH OBSERVATION TARGETS	DETERMINE OPERATING PERIODS BASED ON EARTH OBSERVATION REQUIREMENTS/CONSTRAINTS.	AUTOMATIC	ROUTINE
ORBITAL ANALYSIS	EXPERIMENT OPPORTUNITIES GENERATION	GENERATE PLASMA PHYSICS TARGETS	COMPUTE ORIENTATION AND STRENGTH OF MAGNETIC FIELD IN THE ORBITER COORDINATE SYSTEM	COMPUTE THE ORIENTATION AND STRENGTH OF THE MAGNETIC FIELD RELATIVE TO THE ORBITER POSITION.	AUTOMATIC	ROUTINE
ORBITAL ANALYSIS	EXPERIMENT OPPORTUNITIES GENERATION	GENERATE PLASMA PHYSICS TARGETS	DEVELOP/APPLY CONSTRANTS TO BORB PARAMETERS	DEVELOP PLASMA PHYSICS OBSERVATION PERIODS WITHIN ACCEPTABLE CONDITIONS.	AUTOMATIC	ROUTINE
ORBITAL ANALYSIS	EXPERIMENT OPPORTUNITIES GENERATION	GENERATE PLASMA PHYSICS TARGETS	GENERATE HEMISPHERE OPPORTUNITIES	DEVELOP HEMISPHERE OPPORTUNITIES BASED ON LATITUDE CONSTRAINTS.	AUTOMATIC	ROUTINE
ORBITAL ANALYSIS	EXPERIMENT OPPORTUNITIES GENERATION	GENERATE PLASMA PHYSICS TARGETS	COMBINE CONSTRAINTS TO DETERMINE PLASMA PHYSICS TARGETS	DETERMINE OPERATING PERIODS BASED ON PLASMA PHYSICS REQUIREMENTS/CONSTRAINTS.	AUTOMATIC	ROUTINE

FIGURE 2.3-1. RESOURCE REQUIREMENTS DATA BASE/ACTIVITY SUMMARY DATA

ACTIVITY TIME AND SKILL REQUIREMENTS

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ACTIVITY	CYCLE	CALENDAR TIME(DAYS)	SKILL TYPE	SKILL LEVEL (1-NOV,2-PRO,3-EXP)	MANPOWER (HRS)
COMBINE CONSTRAINTS TO DETERMINE EARTH OBSERVATION TARGETS	B	0	ORBIT	2	1
COMBINE CONSTRAINTS TO DETERMINE EARTH OBSERVATION TARGETS	P	0	ORBIT	2	1
COMBINE CONSTRAINTS TO DETERMINE EARTH OBSERVATION TARGETS	R	0	ORBIT	2	1
COMBINE CONSTRAINTS TO DETERMINE EARTH OBSERVATION TARGETS	U	0	ORBIT	2	1
COMPUTE ORIENTATION AND STRENGTH OF MAGNETIC FIELD IN THE ORBITER COORDINATE SYSTEM	B	1	ORBIT	2	4
COMPUTE ORIENTATION AND STRENGTH OF MAGNETIC FIELD IN THE ORBITER COORDINATE SYSTEM	P	1	ORBIT	2	4
COMPUTE ORIENTATION AND STRENGTH OF MAGNETIC FIELD IN THE ORBITER COORDINATE SYSTEM	R	0	ORBIT	2	1
COMPUTE ORIENTATION AND STRENGTH OF MAGNETIC FIELD IN THE ORBITER COORDINATE SYSTEM	U	1	ORBIT	2	4
DEVELOP/APPLY CONSTRAINTS TO BORB PARAMETERS	B	0	ORBIT	2	1
DEVELOP/APPLY CONSTRAINTS TO BORB PARAMETERS	P	0	ORBIT	2	1
DEVELOP/APPLY CONSTRAINTS TO BORB PARAMETERS	R	0	ORBIT	2	1
DEVELOP/APPLY CONSTRAINTS TO BORB PARAMETERS	U	0	ORBIT	2	1
GENERATE HEMISPHERE OPPORTUNITIES	B	0	ORBIT	1	1
GENERATE HEMISPHERE OPPORTUNITIES	P	0	ORBIT	1	1
GENERATE HEMISPHERE OPPORTUNITIES	R	0	ORBIT	1	1
GENERATE HEMISPHERE OPPORTUNITIES	U	0	ORBIT	1	1
COMBINE CONSTRAINTS TO DETERMINE PLASMA PHYSICS TARGETS	B	0	ORBIT	2	2
COMBINE CONSTRAINTS TO DETERMINE PLASMA PHYSICS TARGETS	P	1	ORBIT	2	4
COMBINE CONSTRAINTS TO DETERMINE PLASMA PHYSICS TARGETS	R	0	ORBIT	2	1
COMBINE CONSTRAINTS TO DETERMINE PLASMA PHYSICS TARGETS	U	0	ORBIT	2	1
MERGE ALL EXPERIMENT TARGET FILES	B	0	ORBIT	1	1
MERGE ALL EXPERIMENT TARGET FILES	P	0	ORBIT	1	1
MERGE ALL EXPERIMENT TARGET FILES	R	0	ORBIT	1	1

FIGURE 2.3-2. RESOURCE REQUIREMENTS DATA BASE/ACTIVITY TIME AND SKILL REQUIREMENTS

SOFTWARE USED BY ACTIVITY DATE 03/19/87

PAGE 3

ACTIVITY NAME	SOFTWARE NAME	TIME REQUIRED FOR USE BY PLANNING CYCLE (HRS)			
		PRELIMINARY	BASIC	UPDATE	REPLANNING
COMBINE CONSTRAINTS TO DETERMINE EARTH OBSERVATION TARGETS	TARGEN	1	1	1	1
COMPUTE ORIENTATION AND STRENGTH OF MAGNETIC FIELD IN THE ORBITER COORDINATE SYSTEM	BORB	1	1	1	1
DEVELOP/APPLY CONSTRAINTS TO BORB PARAMETERS	LTO-2	1	1	1	1
GENERATE HEMISPHERE OPPORTUNITIES	LTO-1	1	1	1	1
COMBINE CONSTRAINTS TO DETERMINE PLASMA PHYSICS TARGETS	TARGEN	4	4	4	4
MERGE ALL EXPERIMENT TARGET FILES	TARGEN	1	1	1	1
PERFORM PARAMETRIC ANALYSIS TO DESIGN/DEVELOP CO-ORBITING TRAJECTORIES THAT SATISFY OBJECTIVES AND CONSTRAINTS	RELMO	10	10	10	0
DEVELOP PRELIMINARY ATTITUDE TIMELINE	CAVA/CAVINP	1	1	1	0
CREATE COMMON FILE FOR ASTAR PROGRAM (DS)	READPI	2	2	2	0
CREATE RESERVE PERIOD FILE (DS)	EDT	8	8	4	0
SCHEDULE SCIENCE OBSERVATIONS (DS)	ASTAR	80	80	80	5
GENERATE ATTITUDE TIMELINE	CAVA/KEYGEN	8	8	8	1
EDIT CURRENT ATTITUDE T/L TO INCORPORATE STS OR OTHER REQMTS	CAVA/CAVINP	1	1	1	0

FIGURE 2.3-3. RESOURCE REQUIREMENTS DATA BASE/SOFTWARE USED BY ACTIVITY

SOFTWARE DESCRIPTION

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SW NAME	SW FUNCTION	MODE OF USE	SKILL REQMTS TYPE	SKILL REQMTS LEVEL	LANGUAGE	LINES	MEMORY (BYTES)	RUNTIME (MIN)
LTO-2	(LIST-DIRECTED TO ON/OFF FILE). THE LTO PROGRAM TAKES AS INPUT A USER SPECIFIED LIST-DIRECTED FILE AND ACCEPTANCE CONDITIONS TO APPLY TO THAT FILE. LTO READS THE INPUT FILE SCANNING FOR PERIODS OF TIME DURING WHICH THE SPECIFIED CONDITIONS ARE SATISFIED. THE OUTPUT IS AN ON/OFF SUBJECT CONTAINING THE TIMES AT WHICH THE SPECIFIED CONDITIONS ARE SATISFIED. THIS OUTPUT SUBJECT MAY BE WRITTEN ON A NEW ON/OFF FILE OR ADDED TO AN EXISTING ONE.	INTERACTIVE	ORBIT	PROFICIENT	FORTRAN	351	1139000	150
LTO-3	(LIST DIRECTED TO ON/OFF FILE). THE LTO PROGRAM TAKES AS INPUT A USER SPECIFIED LIST-DIRECTED FILE AND ACCEPTANCE CONDITIONS TO APPLY TO THAT FILE. LTO READS THE INPUT FILE SCANNING FOR PERIODS OF TIME DURING WHICH THE SPECIFIED CONDITIONS ARE SATISFIED. THE OUTPUT IS AN ON/OFF SUBJECT FILE CONTAINING THE TIMES-AT WHICH THE SPECIFIED CONDITIONS ARE SATISFIED. THIS OUTPUT SUBJECT MAY BE WRITTEN ON A NEW ON/OFF FILE OR ADDED TO A EXISTING ONE.	INTERACTIVE	ORBIT	PROFICIENT	FORTRAN	351	1139000	30

FIGURE 2.3-4. RESOURCE REQUIREMENTS DATA BASE/SOFTWARE DESCRIPTION

SOFTWARE PERIPHERALS REQUIRED DATE 03/17/87

PAGE 1

SOFTWARE NAME	PERIPHERAL REQUIRED
ASEP	TEKTRONIX 4014
ASTAR	ANY TERMINAL
ASTRO	ANY TERMINAL
ATMOS	ANY TERMINAL
BORB	TEKTRONIX 4014
CAVA/CAVINP	TEKTRONIX 4014
CAVA/KEYGEN	TEKTRONIX 4014
CG	VAX TERMINAL
CHECK	VAX TERMINAL
CMDATG	VAX TERMINAL
DEL.CON	VAX TERMINAL
DF/DFRG	TEKTRONIX 4014
DF/DVM	VAX TERMINAL
DF/HFS	VAX TERMINAL
DF/HPFG	VAX TERMINAL
DF/MDRPG	VAX TERMINAL
DF/MWG	VAX TERMINAL
DF/ORS	VAX TERMINAL
DF/PBS	VAX TERMINAL
DF/PCS	VAX TERMINAL
DF/PPCG	VAX TERMINAL
EDT	VAX TERMINAL
ESAL	TEKTRONIX 4014
ESDAT	TEKTRONIX 4014
ESP	VT241,100,TEKTR.
GENMTL	VAX TERMINAL
GIMBAL	ANY TERMINAL
GSOLP	ANY TERMINAL
IDUS	VAX TERMINAL
IPOL	ANY TERMINAL
JOTF	ANY TERMINAL
LANTIM	ANY TERMINAL
LTO	ANY TERMINAL
LWAP	ANY TERMINAL
MET	VAX TERMINAL
MMUALL	VAX TERMINAL

FIGURE 2.3-5. RESOURCE REQUIREMENTS DATA BASE/SOFTWARE PERIPHERALS REQUIRED

ACTIVITY INPUT/OUTPUTS

DATE 03/19/87

ACTIVITY	INPUT/OUTPUT NAME	I/O FORM	SW ASSOC. WITH	TYPE	SOURCE/DESTINATION	CYCLES INPUT/OUTPUT DURING PREL	BASIC	UPDT	RPLNG
COMPUTE ORIENTATION AND STRENGTH OF MAGNETIC FIELD IN THE ORBITER COORDINATE SYSTEM	BORB PAR.	COMPUTER	BORB	O	DEVELOP/APPLY CONSTRAINTS TO BORB PARAMETERS	Y	Y	Y	Y
DEVELOP/APPLY CONSTRAINTS TO BORB PARAMETERS	BORB PAR.	COMPUTER	LTO	I	COMPUTE ORIENTATION AND STRENGTH OF MAGNETIC FIELD IN THE ORBITER COORDINATE SYSTEM	Y	Y	Y	Y
DEVELOP/APPLY CONSTRAINTS TO BORB PARAMETERS	BORB CONSTRAINTS	MANUAL	LTO	I	PI GENERATED (BORB CONSTRAINTS)	Y	Y	Y	Y
DEVELOP/APPLY CONSTRAINTS TO BORB PARAMETERS	BORB CONSTS	COMPUTER	LTO	O	COMBINE CONSTRAINTS TO DETERMINE PLASMA PHYSICS TARGETS	Y	Y	Y	Y
GENERATE HEMISPHERE OPPORTUNITIES	GND TRK	COMPUTER	LTO	I	GENERATE REQUIRED EPHEMERIS DATA FOR OUTPUT	Y	Y	Y	Y
GENERATE HEMISPHERE OPPORTUNITIES	LATITUDE CONSTRAINTS	MANUAL	LTO	I	PI DEVELOPED (HEMISPHERE LATITUDE CONSTRAINTS)	Y	Y	Y	Y
GENERATE HEMISPHERE OPPORTUNITIES	HEMSPR CONSTS	COMPUTER	LTO	O	COMBINE CONSTRAINTS TO DETERMINE PLASMA PHYSICS TARGETS	Y	Y	Y	Y

FIGURE 2-3.6. RESOURCE REQUIREMENTS DATA BASE/ACTIVITY INPUTS/OUTPUTS

COMPUTER INPUT/OUTPUT SUMMARY DATE 03/18/87

PAGE 2

INPUT/OUTPUT NAME	FILE SIZE(BYTES) MAXIMUM	MINIMUM	INPUT/OUTPUT DESCRIPTION
ATT TL	409600	102400	THIS IS AN ON/OFF FILE CONTAINING DATA DEFINING THE ORBITER ATTITUDE TIMELINE. THIS IS A SUBJECT TYPE 16 ON/OFF FILE.
ATT TL (NDF)	10240000	1024000	THIS IS A NAME-DIRECTED FILE CONTAINING DATA DEFINING THE ORBITER ATTITUDE TIMELINE AND ASSOCIATED DATA. INCLUDED ARE ATTITUDE DATA, STATE VECTOR DATA, TARGET DATA, SENSOR DATA, TIME, ATTITUDE RATES DATA, KEYWORDS, AND MANEUVER TIMES.
BORB CONSTS	1024000	512000	THIS IS AN ON/OFF FILE CONTAINING ON/OFF TIMES WHICH REPRESENT TIME PERIODS WHERE CERTAIN PLASMA PHYSICS REQUIREMENTS/CONSTRAINTS HAVE BEEN SATISFIED. THIS IS A SUBJECT TYPE 0 ON/OFF FILE.
BORB PAR.	14336000	4096000	THIS IS A LIST-DIRECTED FILE CONTAINING TIME HISTORIES OF GEOMAGNETIC PARAMETERS. THE DATA DEFINES THE STRENGTH OF THE GEOMAGNETIC FIELD AND THE DIRECTIONS OF THE FIELD AT THE CURRENT ORBITER POSITION.
CAND GSTAR	1024000	409600	THE CANDIDATE GUIDE STAR FILE CONTAINS THE FOLLOWING INFORMATION FOR EACH GUIDE STAR: SCIENCE STAR SEQUENCE NUMBERS AND ID NUMBERS, SCIENCE STAR RIGHT ASCENSION, AND DECLINATION, IPS OPERATION MODE, NUMBER OF GUIDE STARS IN ANNULUS/BONESIGHT REGIONS, GUIDE STAR LOCATION IN SKYMAP CATALOG, AND GUIDE STAR POSITION (ANNULUS OR BORESIGHT).

FIGURE 2.3-7. RESOURCE REQUIREMENTS DATA BASE/COMPUTER INPUT/OUTPUT SUMMARY

MANUAL INPUT OUTPUT SUMMARY DATA

DATE 03/18/87

PAGE 1

INPUT/OUTPUT NAME	TYPE	DOCUMENT INCLUDED IN	INPUT/OUTPUT DESCRIPTION
ATMOS DESIRED VEHICLE ATTITUDE	VERBAL, WRITTEN	N/A	THE DESIRED VEHICLE ATTITUDE FOR THE ATMOS EXPERIMENT IS DEFINE BY TIME, REFERENCE COORDINATE SYSTEM, PITCH, YAW, AND ROLL.
ATTITUDE UPDATES	VERBAL, WRITTEN	N/A	ATTITUDE UPDATES BASED ON ATTITUDE/TDRS ITERATION AND REVIEW CYCLE COMMENTS/INPUTS.
BASIC CO-ORBITING REQUIREMENTS	VERBAL, WRITTEN	EFORD	A DETERMINATION OF THE TYPES OF ORBIT OPERATIONS THAT ARE REQUIRED: PROXIMITY OPERATIONS, DEPLOYMENT, RENDEZVOUS, GRAPPLE/CAPTURE.
BASIC CREW CYCLE	VERBAL/INFORMAL DOCUMENT	N/A	BASIC SLEEP/ WORK CYCLES OBTAINED FROM JSC.
BORB CONSTRAINTS	VERBAL, WRITTEN	N/A	CONSTRAINTS TO CONSIDER WHEN DEVELOPING PLASMA PHYSICS TARGET OPPORTUNITIES INCLUDE: B AZ, B ELEV, B DOT X, L SHELL (TYPICAL).
CDMS DICTIONARY	DOCUMENT	N/A	COMMAND AND DATA MANAGEMENT SYSTEM DICTIONARY (PFDF DOCUMENT). CONTAINS DISPLAY DEFINITIONS.
CDMS SYSTEM DEFINITION	DOCUMENTS	N/A	COLLECTION OF DOCUMENTS THAT DESCRIBE THE CDMS FOR THE FLIGHT IN QUESTION (SPAN,ICD'S,ETC.).
CEL TARGET(S) ELEV ANGLE CONSTS	VERBAL, WRITTEN	N/A	ELEVATION ANGLE CONSTRAINTS RELATIVE TO CELESTIAL OBJECT(S) VIEWING PERIODS.
CELESTIAL TARGETS	VERBAL, WRITTEN	N/A	CELESTIAL TARGET DATA (NUMBER, NAME, RIGHT ASCENSION, AND DECLINATION) ARE INPUT MANUALLY USING THE STAR PROGRAM TO CREATE A CANDIDATE CELESTIAL TARGET FILE.
COMMANDS FROM PI	INFORMAL DOCUMENTS	N/A	CHRONOLOGICAL LISTING OF ALL COMMANDS TO THE PI'S EXPERIMENT.

FIGURE 2.3-8. RESOURCE REQUIREMENTS DATA BASE/MANUAL INPUT/OUTPUT SUMMARY

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Section 3

SPACE STATION MISSION PLANNING CONCEPT AND SOFTWARE REQUIREMENTS

3.1 ACTIVITIES AND ACCOMPLISHMENTS

The objective of this task was to develop a payload mission planning concept consistent with the overall Space Station operations philosophy and to define a system of software requirements maximizing use of the SL MIPS software modules (modified as necessary) to implement the concept.

The approach taken to this task consisted of four subtasks. First, basic definitions, groundrules, and assumptions were established; these pertained to the current Space Station design and operations concepts and philosophies, the scope of mission planning for Space Station, objectives/requirements to be achieved/satisfied by the approach to mission planning, the structure of organizations/personnel involved in mission planning, the number, purpose, and nature of planning cycles for Space Station, and the degree of allocation of mission planning functions between ground-based organizations and the on-board crew. The second subtask involved the construction of a set of functional flow diagrams. The third subtask then involved the identification of modified SL MIPS software modules or new computer programs to automate individual mission planning activities identified in the flow diagrams. The fourth and final subtask involved the summarization and systemization into a hierarchical structure of the new or modified SL MIPS software programs as the basis for preparation of a software development plan in Task 5.

Inputs to this study task were derived from a variety of sources:

- Space Station Program reference documents
- Space Station plans, study reports, white papers, briefings, meeting minutes, etc., published by NASA organizations, contractors, and working groups, including the NASA Space Station Operations Task Force and its panels
- Task 2 products and knowledge pertaining to the Spacelab mission planning process

The products of this task consist of the Space Station payload mission planning concept functional flow diagrams, a summary table describing the new and modified SL MIPS software modules required to implement the SS MPS concept, and the hierarchical structure of software for the SS MPS.

3.2 SS MPS CONCEPT FUNCTIONAL FLOWS

Similar to the Spacelab functional flow diagrams, the SS mission planning concept functional flow diagrams show mission planning cycles and activities by organization and define the interfaces between those organizations; define a hierarchy of mission planning subfunctions, tasks and subtasks; reveal recurring mission planning activities across cycles; and, identify applicable SL payload MIPS software modules or requirements for new software. The SS MPS Top Level Functional Flow is illustrated in Figure 3.2-1. Examples of the detailed flow diagrams for the subsequent levels are presented in Figures 3.2-2 through Figure 3.2-4.

3.3 SOFTWARE REQUIREMENTS

The hierarchical structure of required SS MPS software modules is shown in Figure 3.3-1; the structure is oriented toward the using organizations, and identifies (per the legend) the modified SL MIPS, new and AI-application candidate software programs (Section 4 summarizes the approach and rationale supporting the AI application candidates).

Representative excerpts from the summary table describing the new and modified SL MIPS software modules are presented in Figure 3.3-2 (Note the correlation of each software module to applicable subfunctions/tasks in the SS mission planning concept functional flow diagrams).

For the purposes of assessing the applicability of AI techniques to the SS MPS in Task 4 of the study, and for generating the Software Development Plan in Task 5, the computer programs identified in Figure 3.3-1 were grouped into software sets, i.e., groups of programs of a similar nature at the same hierarchical level. The software sets are presented in Table 3.3-1.

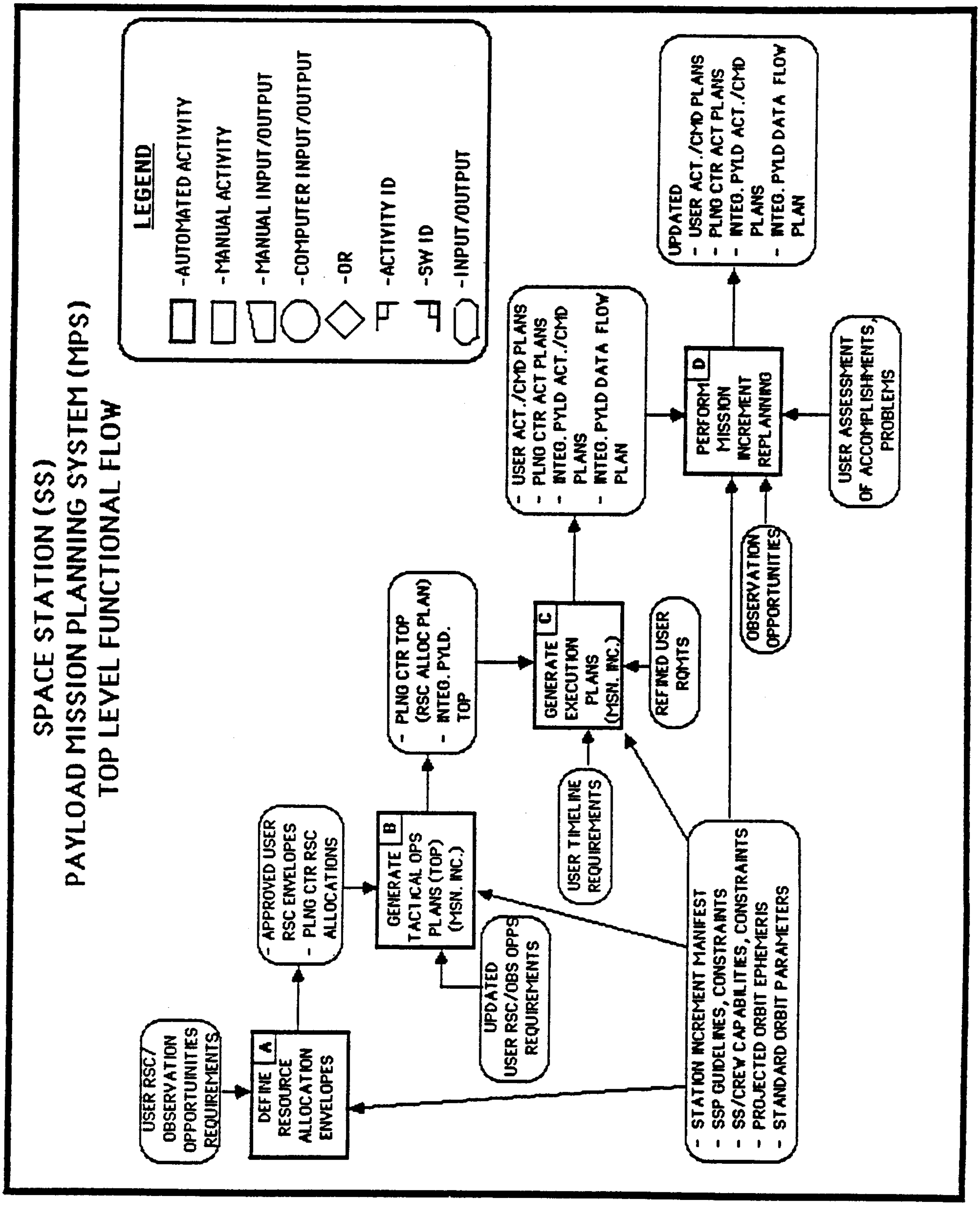

FIGURE 3.2-1. SS MPS TOP LEVEL FUNCTIONAL FLOW

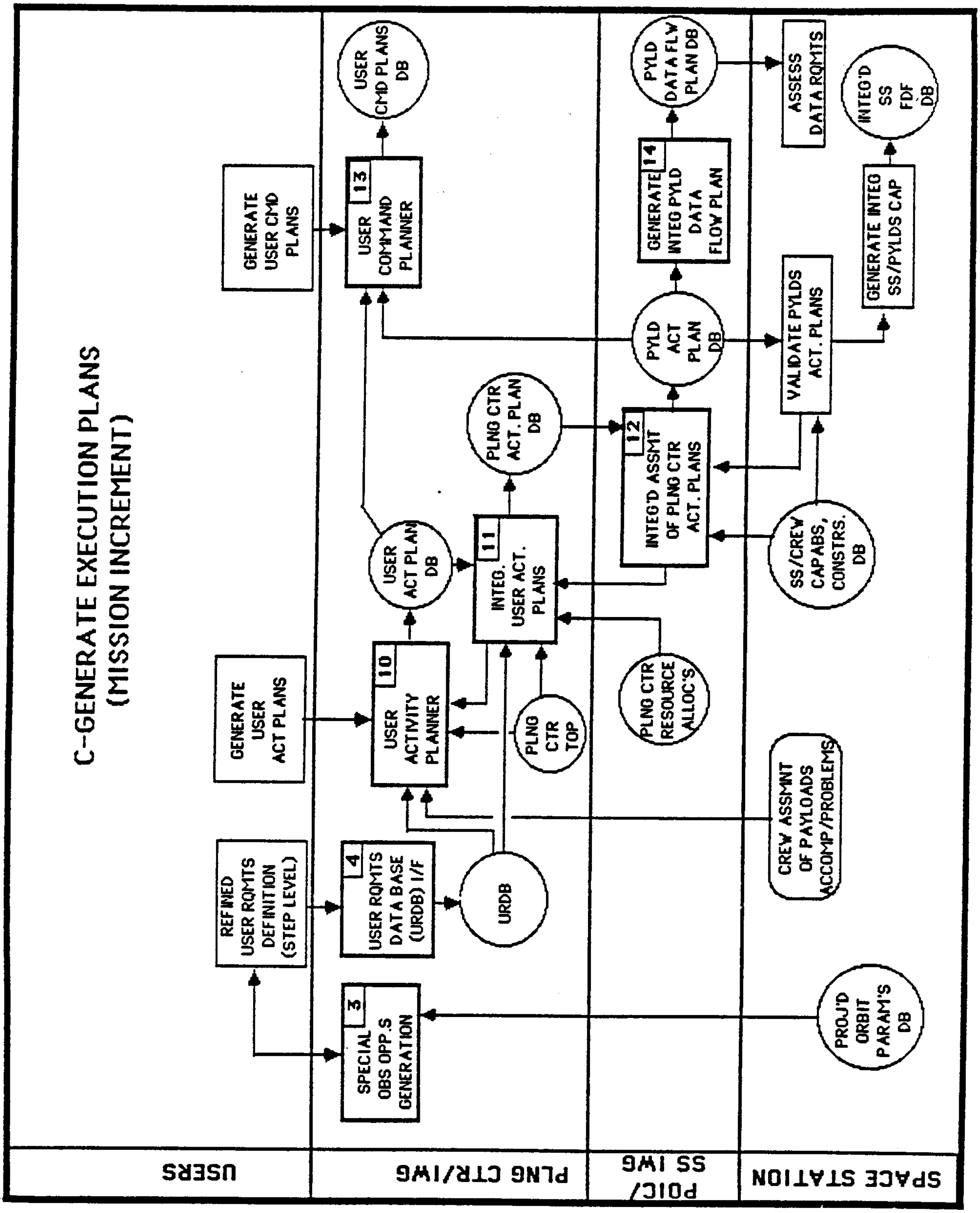

FIGURE 3.2-2. EXCERPT OF PLANNING CYCLE LEVEL FUNCTIONAL FLOWS

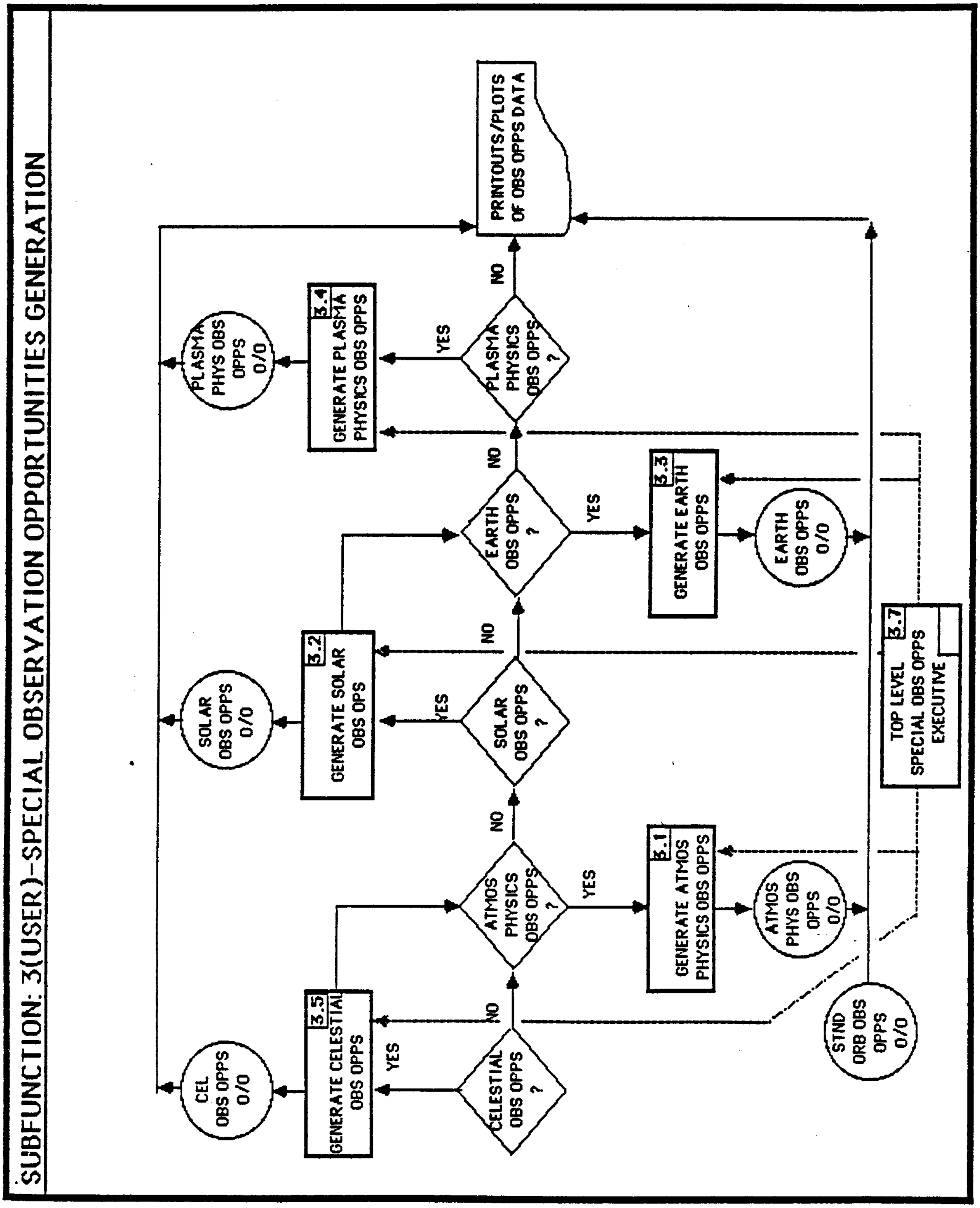

FIGURE 3.2-3. EXCERPT OF SUBFUNCTION LEVEL FUNCTIONAL FLOWS

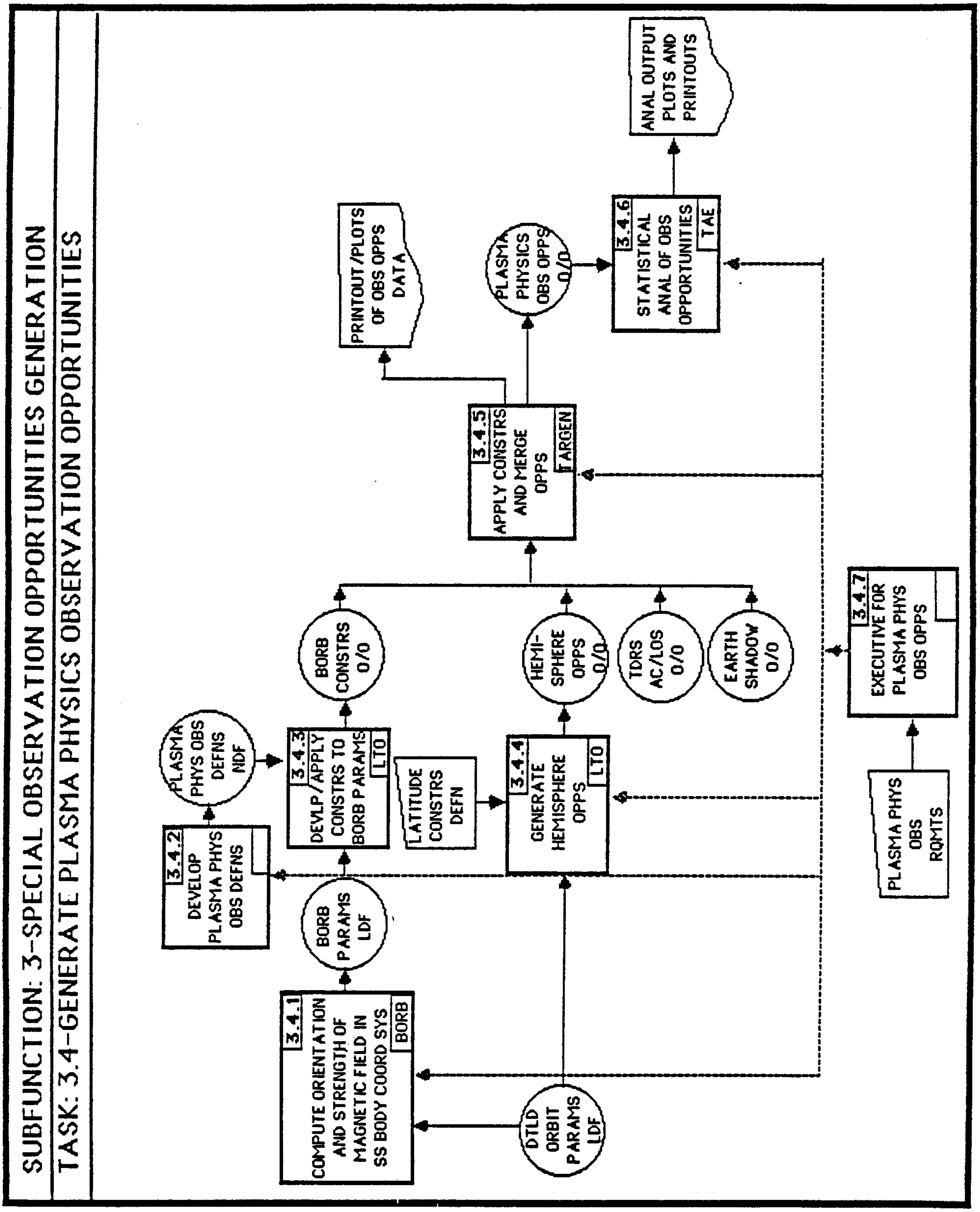

FIGURE 3.2-4. EXCERPT OF TASK LEVEL FUNCTIONAL FLOWS

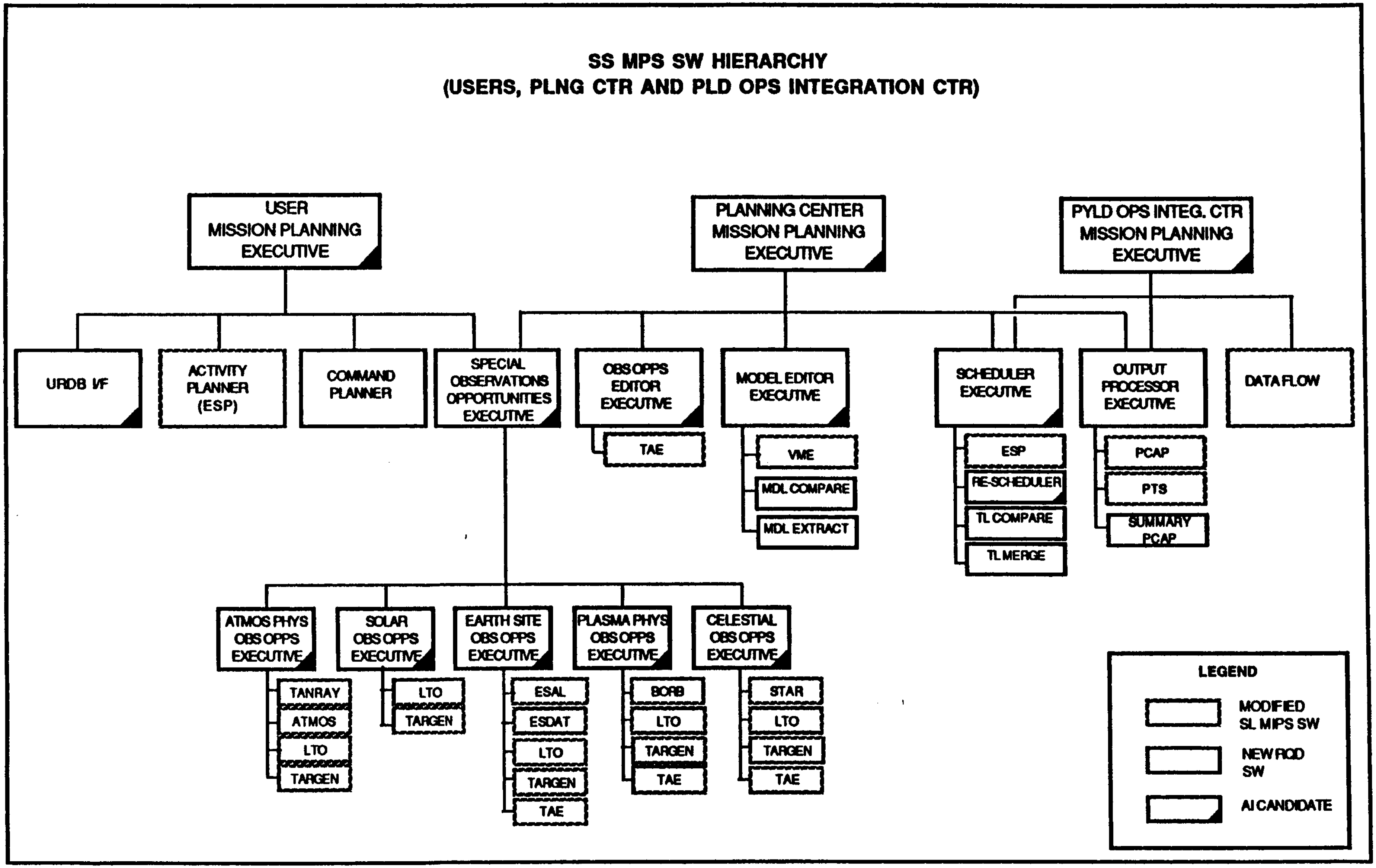

FIGURE 3.3-1. SS MPS SW Hierarchy

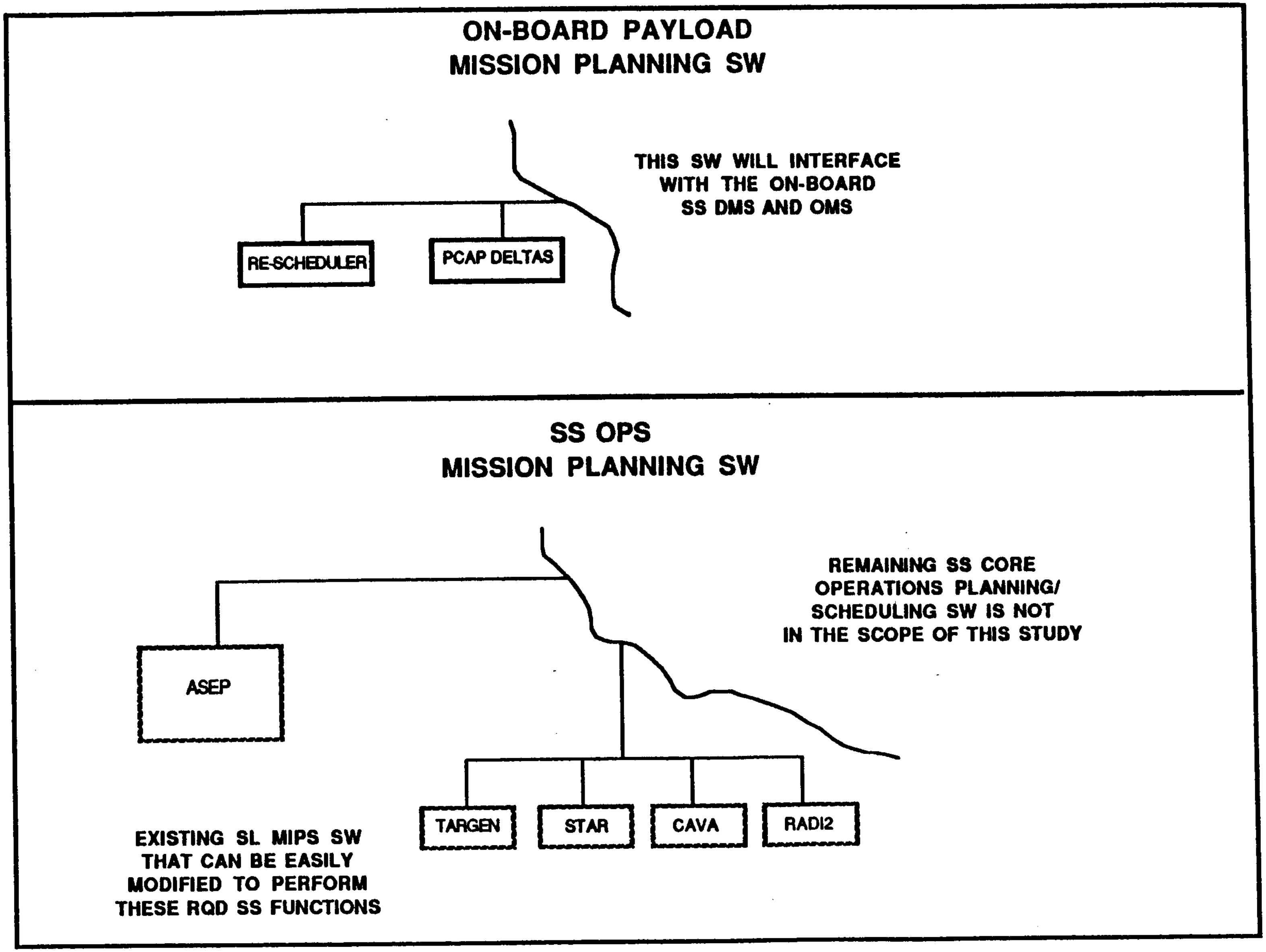

FIGURE 3.3-1. SS MPS SW HIERARCHY (CONT'D)

SS MPS SOFTWARE REQUIREMENTS SUMMARY

SW MODULE NAME	NEW OR MODIFIED	SW MODULE FUNCTIONAL DESCRIPTION	APPLICABLE SUBFUNCTION/TASK
EARTH SITE EXEC	NEW	EXPERT SYSTEM EXECUTIVE THAT AIDS THE USER/MSN PLANNER IN DEFINING EARTH SITE OBSERVATION RQMTS AND CALCULATING OBSERVATION OPPORTUNITIES. SYSTEM MUST PROVIDE A USER FRIENDLY INTERFACE WITH ON-LINE HELP AND ALSO INTERFACE WITH THE APPLICABLE CALCULATION ROUTINES (ESDAT, ESAL, LTO,TARGEN,TAE). ACTUAL ROUTINE CALLS SHALL BE AS TRANSPARENT AS POSSIBLE TO THE USER. THIS EXEC CONTAINS FEATURES IDENTICAL TO THE ATMOS PHYS. EXECECUTIVE.	3.3.6 EXEC FOR EARTH SITE OBS OPPS
TAE	MODIFIED	SEE SL MIPS DB- STATISTICAL ANALYSIS ROUTINE WILL BE CALLED BY ORBITAL ANALYSIS EXECUTIVE PROGRAMS. O/O FILES WILL NOT BE REFORMATED AND BUILDING NEW SUBJECTS AND EDITING DATA WILL BE DONE IN THE O/O FILE FORMAT. MUST ALSO BE MODIFIED TO EXTRACT USER TIME PREFERENCES DIRECTLY FROM THE URDB. INPUT FILES: MSN OBS OPPS O/O OR URDB OUTPUT FILES: MSN OBS OPPS O/O	3.3.5 STATISTICAL ANAL OF OBS OPPS 3.4.6 STATISTICAL ANAL OF OBS OPPS 3.5.5 STATISTICAL ANAL OF OBS OPPS 5.1.1 EXTRACT USR TIME PREFERENCES 5.1.2 BUILD NEW SUBJECTS IF RQD 5.1.3 STATISTICAL ANALYSIS OF OBS OPPS 5.1.4 OBS OPPS DATA EDITING 8.1.1 EXTRACT USR TIME PREFERENCES 8.1.2 BUILD NEW SUBJECTS IF RQD 8.1.3 STATISTICAL ANALYSIS OF OBS OPPS 8.1.4 OBS OPPS DATA EDITING
BORB	MODIFIED	SEE SL MIPS DB-MODIFIED TO READ DTLD ORBIT PARAMS LDF INSTEAD OF ASCN NODE FILE. CAPABILITY TO HANDLE ATT TL O/O FILE IS NO LONGER REQUIRED. PROGRAM WILL BE DRIVEN BY PLAMSA PHYS EXECUTIVE. INPUT FILES:DTLD ORBIT PARAMS LDF OUTPUT FILES: BORB PARAMS LDF	3.4.1 COMPUTE ORIENTATION AND STRENGTH OF MAGNETIC FIELD IN SS BODY COORD SYS 3.4.2 DEVELOP PLASMA PHYSICS OBS DFNS

FIGURE 3.3-2. EXCERPT OF SS MPS SOFTWARE REQUIREMENTS SUMMARY TABLE

SS MPS SOFTWARE REQUIREMENTS SUMMARY

PAGE 14

SW MODULE NAME	NEW OR MODIFIED	SW MODULE FUNCTIONAL DESCRIPTION	APPLICABLE SUBFUNCTION/TASK
URDB I/F	NEW	EXPERT SYSTEM THAT GUIDES/PROMPTS USERS IN ENTERING FUNCTIONAL REQUIREMENTS INTO THE DATA BASE TO PROVIDE MISSION PLANNERS THE APPROPRIATE INFORMATION FOR PLANNING AND SCHEDULING. THE SYSTEM SHOULD ALLOW INTER-ACTIVE FORM EDITING BY THE USER WITH ON-LINE HELP, DATA ENTRY RULES AND MEANINGFUL DEFAULT VALUES. THE TYPES OF REQUIREMENTS TO BE INCLUDED ARE; RQD RESOURCE VECTORS (POWER, CREW,THERMAL, DATA,ETC.); RQD OBSERVATIONS DEFINITIONS; OPERATIONAL CONSTRAINTS(INHIBITS, ETC.); SEQUENCING,CONCURRENCY RQMTS; AND MIN/MAX #OF PERF-ORMANCES, DURATIONS. THE DB INTERFACE MUST PROVIDE THE CAPABILITY TO RECOGNIZE REQUESTS/INPUTS OUTSIDE OF ITS KNOWLEDGE DOMAIN AND REQUEST HUMAN EXPERT ASSISTANCE WHEN KNOWLEDGE BASE IS INADEQUATE. THE SYSTEM SHOULD BE ABLE TO INTELLIGENTLY UPGRADE DEFAULT VALUES BASED UPON LATEST INPUT DATA FROM USER. THE SYSTEM SHOULD GENERALIZE LOWER LEVEL DETAILS INTO UPPER LEVEL REQUIREMENTS. ALL REQUIREMENTS SHOULD BE CHECKED FOR CONSTRAINTS IN ALL SIX DISCIPLINES. OUTPUT REQUIREMENTS SHALL HAVE ALL ASSUMPTIONS NOTED AND CONFIDENCE FACTORS (E.G. 90%) ASSIGNED.	4 USER REQUIREMENTS DATA BASE I/F

FIGURE 3.3-2. EXCERPT OF SS MPS SOFTWARE REQUIREMENTS SUMMARY TABLE (CONT'D)

TABLE 3.3-1. SS MPS SOFTWARE SETS

NEW SOFTWARE

SET A - SPECIAL OBS OPPS EXECUTIVES
- TOP LEVEL
- ATMOS PHYS
- SOLAR
- EARTH SITE
- PLASMA PHYSICS
- CELESTIAL

SET B - URDB I/F

SET C - EDITOR EXECUTIVES
- MODEL EDITOR EXEC
- OBS OPPS EDITOR EXEC
- SCHEDULER EXEC

SET D - RE-SCHEDULER

SET E - SYSTEM EXECUTIVES (PHASE I)
- USER MPS EXEC
- PLANNING CENTER MPS EXEC
- POIC MPS EXEC

SET F - SYSTEM EXECUTIVES (PHASE II)
- USER MPS EXEC
- PLANNING CENTER MPS EXEC
- POIC MPS EXEC

SET G - COMMAND PLANNER

SET H - NEW TIMELINE ANALYSIS MODULES
- MDL EXTRACT
- MDL COMPARE
- TL COMPARE
- TL MERGE
- PCAP DELTAS
- SUMMARY PCAP

SET L - OUTPUT PROCESSOR EXEC

MODIFIED SL MIPS SOFTWARE

SET I - TIMELINE ANALYSIS
- ESP
- PCAP
- PTS
- TAE
- VME

SET J - ORBIT ANALYSIS
- ASEP
- ATMOS
- BORB
- CAVA
- ESAL
- ESDATA
- LTO
- RADI2
- STAR
- TANRAY
- TARGEN

SET K - DATA FLOW ANALYSIS
- PROFILE
- MISSION WINDOWS
- ONBOARD RECORDER SCHEDULAR
- POSSIBLE FORMATS
- FORMAT SCHEDULAR
- POSSIBLE POCC CONFIGURATIONS
- POCC CONFIGURATION SCHEDULAR
- PLAYBACK SCHEDULAR
- INTERACTIVE DATA UPDATE SYSTEM
- VERIFICATION
- COMPARE TDRS
- COMPARE MODELS
- DATA MANAGEMENT CHECKLIST
- DATA SCHEDULE FILE
- ANTENNA DISPLAY
- IDMS LIBRARY

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Section 4

ARTIFICIAL INTELLIGENCE APPLICATIONS

4.1 ACTIVITIES AND ACCOMPLISHMENTS

The objectives of this task were to:

(1) Define AI techniques that could be applied to SS MPS tasks.
(2) Identify and evaluate all tasks that could use the AI techniques.
(3) Recommend a methodology for implementation of the identified AI tasks.

These objectives were accomplished as illustrated in Figure 4.1-1. Two areas of effort contributed to accomplishment of the objectives specified above. The first effort was to conduct a survey of the current AI technology. The second effort was to compile a list of desired criteria for an AI software development program. Both efforts increased the quality and scope of the recommended hardware and software methodology.

4.2 DEFINITION OF ARTIFICIAL INTELLIGENCE

Artificial Intelligence is the emulation of human intelligence and thought processes by computational models. It is the branch of Computer Science concerned with designing intelligent computer systems that exhibit the characteristics associated with intelligence in human behavior - reasoning, understanding language, solving problems, etc.

Expert systems are AI programs that are designed to execute a highly specialized and difficult task with the proficiency of a human expert. They employ domain-specific problem-solving strategies as opposed to broad, general-purpose strategies.

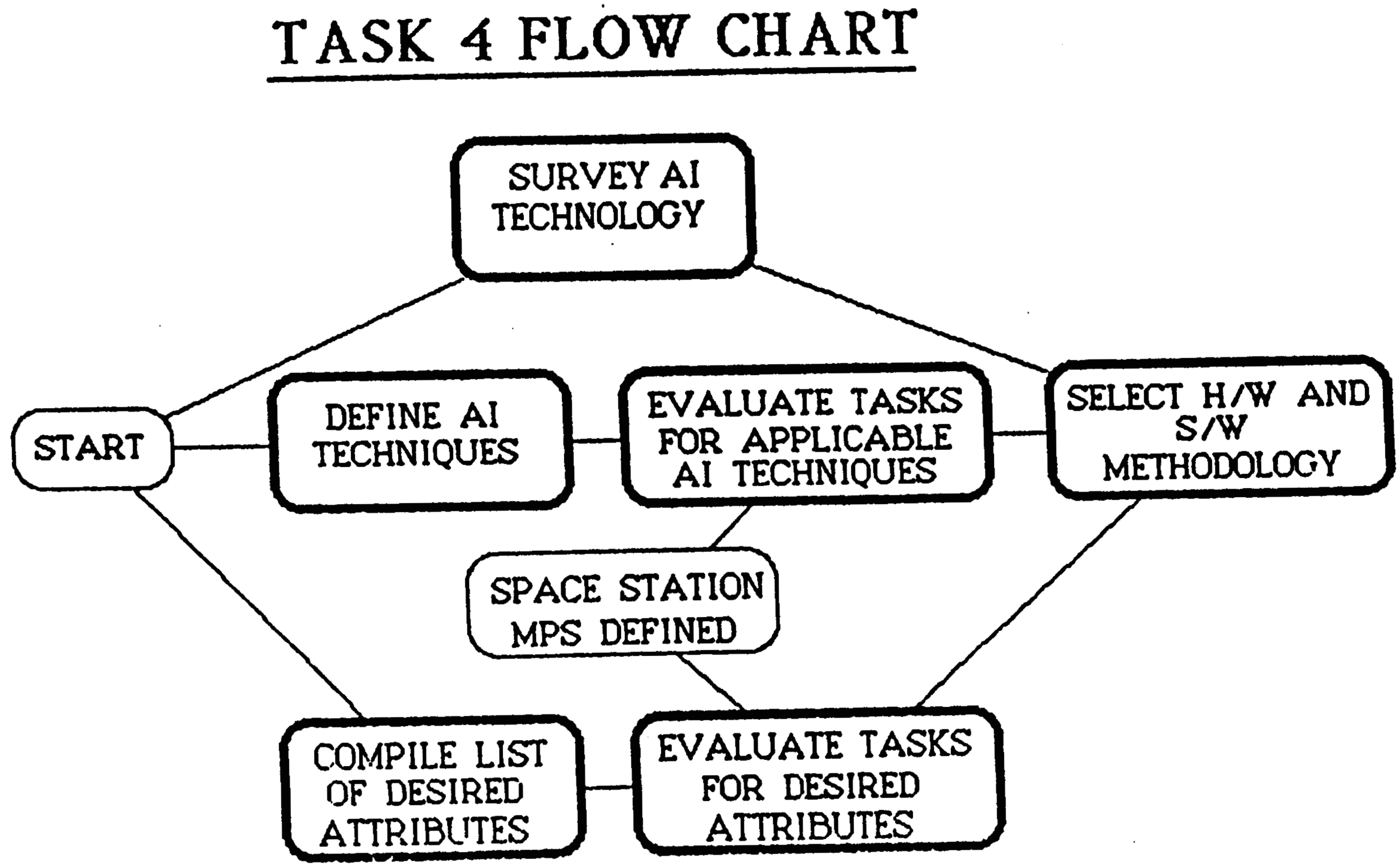

FIGURE 4.1-1. AI TASK FLOW

4.3 ASSUMPTIONS PRIOR TO CANDIDATE EVALUATION

Experience gained from the early phases of the project allowed several assumptions to be made prior to evaluation of the SS MPS candidates.

4.3.1 ADA Software

It is assumed that all new non-AI mission planning software tasks will be coded in ADA for compatibility with Space Station program requirements.

All AI techniques can be implemented in LISP, PROLOG or ADA. LISP and PROLOG have only a few advantages over ADA.

4.3.2 Specialized AI Hardware

If specialized AI hardware is required, assume a Symbolics architecture. LISP and PROLOG are not viable languages unless executed on specialized AI processors. Symbolics is the best processor currently on the market.

The execution of LISP on coprocessor boards installed in conventional computers is not considered; however, their emergence on the market is imminent.

4.3.3 Conventional Hardware

Assume a DEC VAX architecture for all ADA software implementations.

4.3.4 Candidate Evaluation Criteria

The criteria for candidate evaluation are not discrete. They are frequently interrelated.

The criteria are qualitative rather than quantitative. Also, not all criteria are of equal importance.

The evaluation of each software set against the criteria is subjective. The evaluation is highly dependent on definitive information about AI techniques and Space Station operations concepts.

4.4 DESIRED ATTRIBUTES OF MPS TASKS

This list of desired attributes is based upon industry accepted standards for a software development project. Several attributes have been added or modified to tailor them to software projects employing AI techniques.

The desired attributes for candidate MPS tasks are shown in Figure 4.4-1. Each software set received a "+" if the set contained the desired attribute and a "-" if the attribute was missing and could cause potential problems in the implementation of the task.

ATTRIBUTES OF MPS TASKS

	TASK GROUP											
	A	B	C	D	E	F	G	H	I	J	K	L
TASK DOMAIN												
Domain is bounded and stable	+	–	+	+	–	–	+	+	+	+	–	–
Domain is specialized and detailed	+	+	+	+	+	–	–	+	+	+	+	+
TASK EXPERTISE												
Expertise to be lost	+	+	+	+	+	+	–	+	+	+	+	+
Expertise is scarce	+	+	–	+	+	+	–	+	+	+	+	+
Single point expert	+	–	+	+	–	–	–	+	+	+	+	+
Expert is dedicated	+	+	+	+	–	–	+	+	+	+	+	+
TASK INTERFACES AND METHODS												
System can monitor real world	+	–	+	+	–	–	–	+	+	+	+	+
I/O and methods can be defined	–	–	+	–	+	–	–	+	+	+	+	+
Debugging the software	+	+	+	+	–	–	+	+	+	+	+	+
ORGANIZATIONAL ISSUES												
Required Documentation	+	+	+	+	+	+	+	+	+	+	+	+
Configuration control	+	+	+	+	+	+	+	+	+	+	+	+
System acceptance testing	+	–	+	+	–	–	+	+	+	+	+	+
MANAGEMENT ISSUES												
Realistic schedules and milestones	+	+	+	+	–	–	+	+	+	+	+	+
Resource comittment	+	+	+	+	+	+	+	+	+	+	+	+
Low initial cost	+	–	+	–	–	–	+	+	+	+	+	+
Long term manhour savings	+	+	–	+	+	+	–	+	+	+	+	+
PROPOSED USERS OF TASK												
User acceptance	+	–	+	+	–	–	+	+	+	+	+	+

SOFTWARE SETS

A - SPECIAL OBS OPPS EXECUTIVES
B - USER REQUIREMENTS DATA BASE INTERFACE
C - EDITOR EXECUTIVES
D - RESCHEDULER
E - SYSTEM EXECUTIVES PHASE I
F - SYSTEM EXECUTIVES PHASE II
G - COMMAND PLANNER
H - NEW TIMELINE SOFTWARE
I - MODIFIED TIMELINE SOFTWARE
J - MODIFIED ORBITAL MECHANICS SOFTWARE
K - MODIFIED DATA FLOW SOFTWARE
L - OUTPUT PROCESSOR EXECUTIVE

FIGURE 4.4-1. ATTRIBUTES OF MPS TASKS

4.5 ARTIFICIAL INTELLIGENCE TECHNIQUES

An attempt was made to comb through the many books describing AI techniques and pull out the techniques that demonstrate advantages over conventional programming techniques.

The definition of an AI technique versus a conventional technique is subjective and a source of disagreement within the programming community. The boundary between the two is constantly shifting. Many AI techniques were first implemented in LISP or PROLOG and then found their way to conventional implementations in FORTRAN, PASCAL or C. For our definition, AI techniques are most easily implemented in ADA, LISP or PROLOG, while implementations in FORTRAN, etc., are considered to be strictly conventional. Note that ADA holds the middle ground, being a derivative of PASCAL and FORTRAN, but designed to easily implement complex AI techniques.

The AI techniques identified as advantageous over conventional programming techniques are listed on Figure 4.5-1. The functions of each software set were evaluated against the list and given a "+" if any of the task functions could be implemented using an AI technique.

4.6 METHODOLOGY FOR CANDIDATE IMPLEMENTATION

The methodology for hardware and software host selection is illustrated in Figure 4.6-1. The software sets were evaluated against the attributes described below and given a "+" if they exhibited a need for that attribute. They were given a "-" if they had no need for that attribute.

4.7 RESULTS OF EVALUATION

The evaluation of each SS MPS task against the Desired Attributes criteria produced a list of benefits and concerns for the implementation of each software set.

The summation and weighing of all evaluations performed previously, resulted in the task methodology recommended for implementation. This recommendation is shown on the bottom half of Figure 4.6-1.

Fourteen tasks were selected as candidates for using AI techniques. Thirteen tasks are recommended to be delivered in ADA on the VAX.

One task is recommended to be delivered on the Symbolics in LISP with a hardware interface to the VAX. At a future date it should be ported to the VAX prior to installation on-board the Space Station.

Four tasks are recommended for prototyping on the Symbolics Machine.

Three tasks are recommended for implementation in the Spacelab MIPS.

AI TECHNIQUES FOR MPS TASKS

	TASK GROUP A	B	C	D	E	F	G	H	I	J	K	L
REPRESENTATION OF KNOWLEDGE												
Production Rules	+	+	+	+	+	+	+		+		+	+
State space representations				+		+						
Frames, Object oriented programming	+	+	+	+	+	+	+				+	+
Scripts	+	+	+	+	+	+	+					
Semantic nets					+							
MANIPULATION OF KNOWLEDGE												
Abstraction	+	+	+	+	+	+	+					
Inheritance	+	+		+	+	+					+	
Pattern matching	+	+	+	+	+	+	+					
Augmented transition networks					+							
Chaining		+		+	+	+					+	
CONTROL STRATEGIES												
Demons/Methods	+	+	+	+	+	+	+	+	+	+	+	+
Blackboards	+	+	+	+	+	+						
UNCERTAINTY MANAGEMENT												
Fuzzy logic	+	+	+		+	+	+					
Dempster shaeffer theory		+	+			+						
Baysian inference						+						
AUTOMATIC PROGRAMMING												
Module selection and sequencing	+		+		+							
Learning capability						+						
EXPLANATION CAPABILITY	+	+	+	+	+	+	+	+	+	+	+	+
META KNOWLEDGE	+	+	+		+	+	+					
NATURAL LANGUAGE INTERFACES					+							
DESIGN CAPTURE		+				+						+

SOFTWARE SETS

A - SPECIAL OBS OPPS EXECUTIVES
B - USER REQUIREMENTS DATA BASE INTERFACE
C - EDITOR EXECUTIVES
D - RESCHEDULER
E - SYSTEM EXECUTIVES PHASE I
F - SYSTEM EXECUTIVES PHASE II
G - COMMAND PLANNER
H - NEW TIMELINE SOFTWARE
I - MODIFIED TIMELINE SOFTWARE
J - MODIFIED ORBITAL MECHANICS SOFTWARE
K - MODIFIED DATA FLOW SOFTWARE
L - OUTPUT PROCESSOR EXECUTIVE

FIGURE 4.5-1. AI TECHNIQUES FOR MPS TASKS

AI METHODOLOGY FOR MPS TASKS

	TASK GROUP											
	A	B	C	D	E	F	G	H	I	J	K	L
VAX vs. SYMBOLICS												
Commercial support	+	–	+	+	+	+	+	+	+	+	+	+
Real time environment	+	–	+	+	+	+	+	+	+	+	+	+
Many users	+	+	–	+	+	+	+	+	+	+	+	+
ADA LANGUAGE												
Standardization	+	+	+	+	+	+	+	+	+	+	+	+
Size of source code	+	+	+	+	+	+	+	+	+	+	+	+
Capability to implement AI techniques	+	+	+	+	+	+	+	+	+	+	+	+
LISP LANGUAGE												
Rapid prototype environment	–	+	–	+	+	+	–	–	–	–	–	–
LISP language advantages	–	+	–	+	–	+	–	–	–	–	–	–
Tools available	–	+	–	–	+	+	–	–	–	–	–	–
PROLOG LANGUAGE												
Predicate calculus	–	+	–	+	+	+	–	–	–	–	–	–
Parallel processing	–	–	–	+	+	+	–	–	–	–	–	–
RECOMMENDED METHODOLOGY												
Deliver on VAX in ADA (no AI)								+	+	+	+	+
Deliver on VAX in ADA (use AI)	+	+	+		+	+	+					
Prototype on SYMBOLICS in LISP		+		+	+	+						
Deliver on SYMBOLICS linked to VAX				+								
Implement in Spacelab MIPS	+	+		+								

SOFTWARE SETS

A - SPECIAL OBS OPPS EXECUTIVES
B - USER REQUIREMENTS DATA BASE INTERFACE
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K - MODIFIED DATA FLOW SOFTWARE
L - OUTPUT PROCESSOR EXECUTIVE

FIGURE 4.6-1. AI METHODOLOGY FOR MPS TASKS

4.8 CONCLUSIONS AND RECOMMENDATIONS

4.8.1 AI Technology

AI technology is still very young. The experience base of expert systems performance is small compared to conventional programs. However, the systems in existence do strongly support the many advantages of incorporating this technology into the workplace. AI has proven effective in solving many of the problems where conventional programs fail.

4.8.2 Hardware/Software Architecture

The conclusion to largely use ADA on a VAX is also supported by a study conducted by MDAC-HB for the JSC Space Station Phase B contract.

The largest value of LISP and PROLOG is in the rapid prototyping environment.

4.8.3 Software Tools

Use is recommended during prototyping of an expert system development tool and a natural language development tool.

An in-depth technology survey, with the targeted MPS candidates in mind, should be performed immediately prior to purchase of any off-the-shelf AI tools.

Section 5

SOFTWARE DEVELOPMENT PLAN

5.1 TASK OVERVIEW

The objective of this task was to generate a Software Development plan for the definition, design and implementation of the SS MPS.

The approach taken to this task consisted of four subtasks. First, assumptions inherent in the generation of the SW Development Plan were identified; these pertained to SW development facilities, computer operating systems, coding languages and standards, required formal reviews, required documentation, etc. The second subtask involved developing a technical description of the project - SW requirements, SW hierarchy, etc., and a detailed description of the activities required to successfully complete the development project. Based on the assumptions of subtask 1 and the descriptions of subtask 2, subtask 3 was performed to generate cost estimates for individual or sets of required SS MPS computer programs in terms of manpower and schedule using the Constructive Cost Model (COCOMO), and integrating these into project level manpower requirements and schedule recommendations. The fourth and final subtask was to document and publish the SW Development Plan.

Inputs to this study task were derived from:

- Task 3 products (SS MPS Functional Flows and SW Requirements Summary)
- Task 4 products (AI recommendations and implementation requirements)
- COCOMO Model
- Existing SW development plans (boilerplates)

The product of this task is the SS MPS SW Development Plan, which constitutes Volume III of the Study final report.

5.2 SOFTWARE DEVELOPMENT PLAN DESCRIPTION

The SW Development Plan includes an introduction, a technical description of the project, a detailed description of the project activities, the SW development schedules, manpower requirements and an explanation of the methodology and assumptions utilized for the estimates, and a detailed description of the SW procedures and practices recommended to be applied to the project.

The recommended SS MPS Project Top Level Schedule is shown in Figure 5.2-1. Representative lower level schedules for individual software sets are shown in Figure 5.2-2. The estimated manpower requirements are 4841 man months for the entire project. If the SS MPS was developed without the benefit of the Spacelab MIPS software the estimated total is 9612 manmonths. Representative excerpts of the manpower requirements by project phase for individual software sets are shown in Figure 5.2-3.

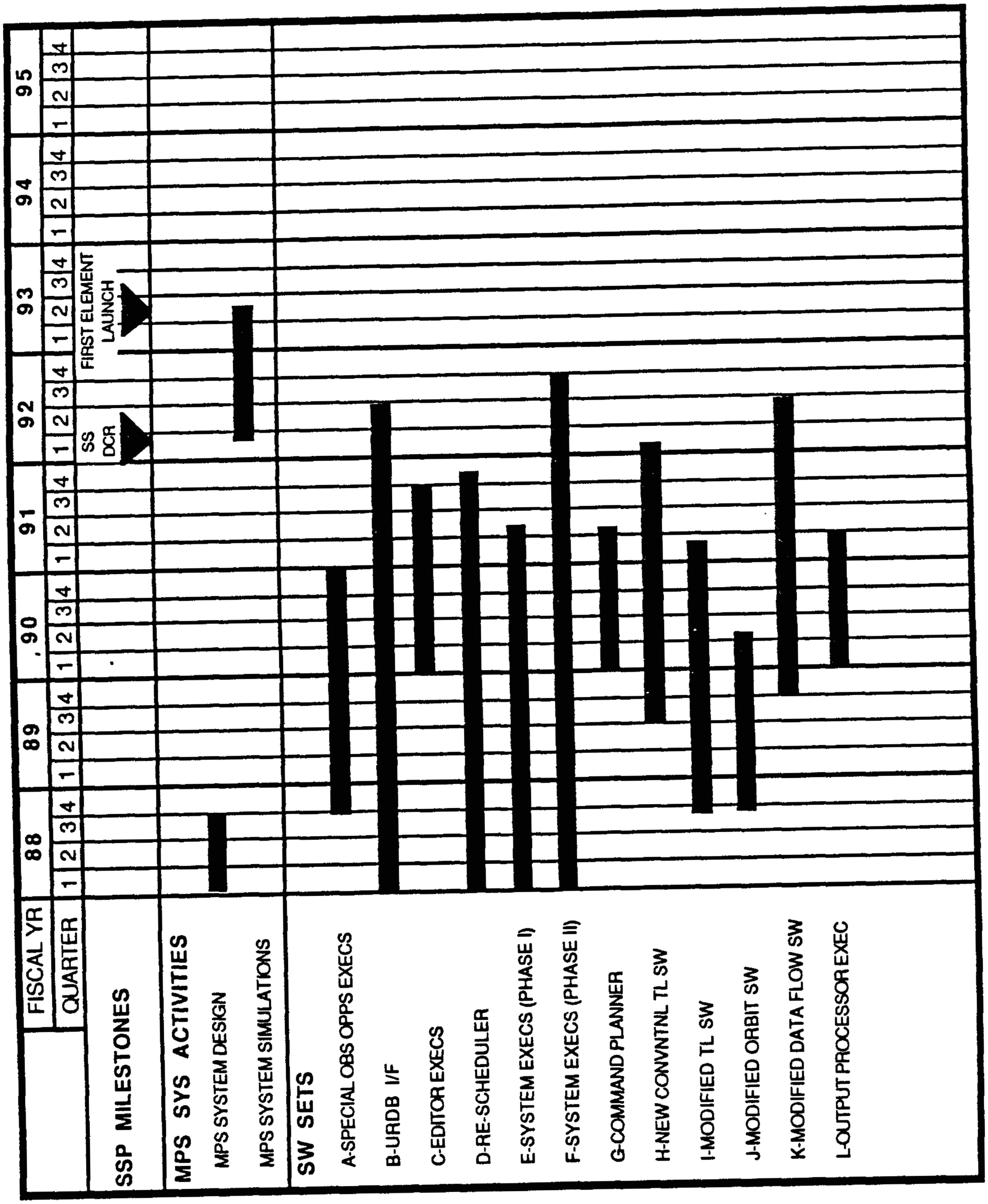


FIGURE 5.2-1. SS MPS TOP LEVEL SCHEDULE

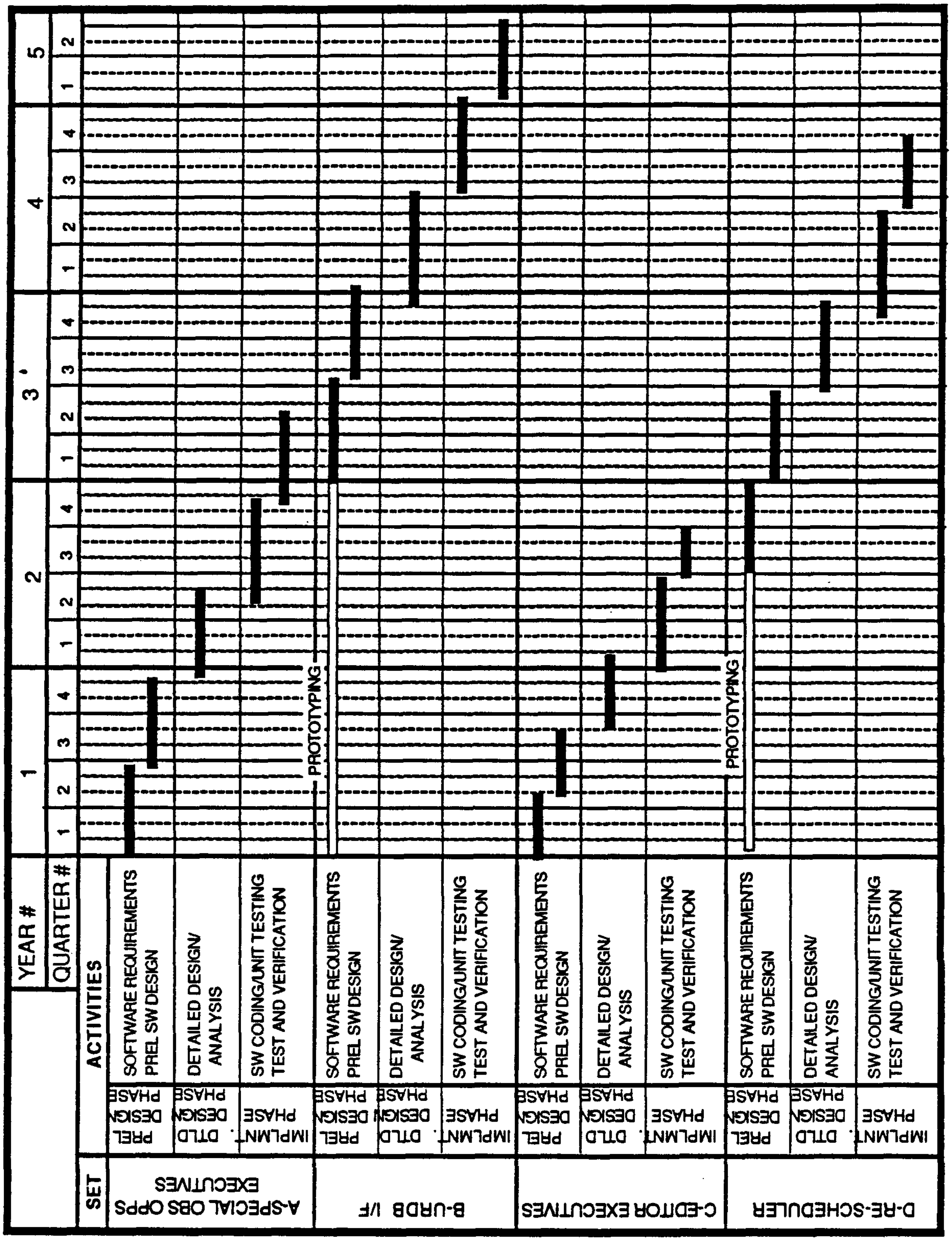
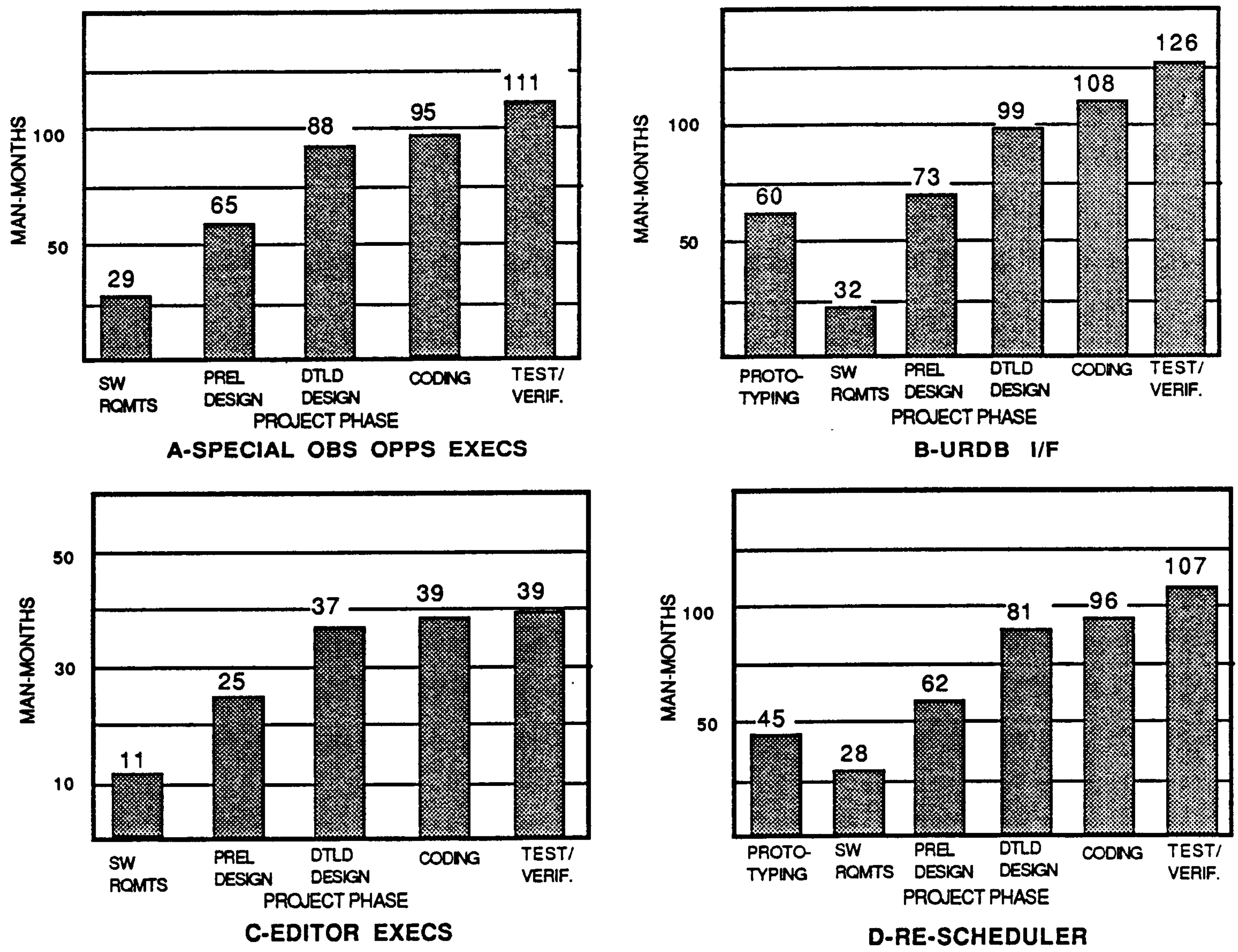


FIGURE 5.2-2. REPRESENTATIVE SS MPS LOWER LEVEL SCHEDULES



FIGURES 5.2-3. REPRESENTATIVE LOWER LEVEL MANPOWER REQUIREMENTS BY PHASE

Section 6

CONCLUSIONS AND RECOMMENDATIONS

Based on the results of the SS MPS Development Study summarized in the previous sections, the following conclusions have been drawn:

1) A detailed definition of the Spacelab payload mission planning process and SL MIPS software has been derived; this definition (functional flow diagrams and data base) will be of great value for training Spacelab mission planning personnel and for assessing and improving the process.

2) A baseline concept for performing SS manned base payload mission planning has been developed; this concept is consistent with current Space Station design/operations concepts and philosophies; however, those concepts and philosophies are the results of Phase B studies and will therefore gain further definition and changes as the Space Station Program progresses.

3) SS MPS software requirements have been defined. These software requirements make maximum use of SL MIPS software with modifications, but do include requirements for new software to accommodate the complexity of the SS mission planning concept and to maximize automation of the concept. Also, requirements for new software include candidate programs for the application of AI techniques to capture and make more effective use of mission planning expertise and to involve SS users directly in the mission planning process.

4) A SS MPS Software Development Plan has been developed which phases efforts for the development of software to implement the SS mission planning concept. The efforts are phased for the immediate start of development of long-lead-time software programs, but for delayed development of programs with a high dependence on SS design/operations concepts. The development schedule, relative to the current overall Space Station Program schedule, indicates the development effort should begin as soon as possible.

5) The estimated manpower requirements to develop the SS MPS are significant; however, the scope of the SS mission planning problem is significant and the process of development is recommended to be highly structured and rigidly controlled. Nonetheless, the software system concept is intended to provide uniform methods of planning payload operations across all equivalent planning levels in order to facilitate the integration of planning, and is intended to maximize the automation of mission planning to minimize long-term mission planning costs.

Based on the conclusions above, the following recommendations are offered:

1) Use the definition (functional flows and data base) of the Spacelab payload mission planning process and software to train mission planning personnel and to evaluate and improve the process. As improvements are made, update the flow diagrams and data base.

2) Proceed with implementation of the SS MPS Development Plan, including the structured and controlled process for software development.

3) Maintain the SS mission planning concept, software system concept, and Software Development Plan consistent with SS design/operations concepts and program schedules.

4) Use Spacelab mission planning as a test bed for testing prototypes of AI applications.